

Palestine Polytechnic University  
College of Engineering



**Purifying Drinking Water Process Energized by Renewable  
Solar Energy**

By:

Islam Tuffaha

Najeeb Sharawneh

Mohamad Nofal

Supervised By:

Prof. Sameer Hanna

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## الإهداء

السلام عليكم ورحمة الله تعالى وبركاته

أيام مضت وها نحن اليوم نقطف ثمار أعواما من الجد والاجتهاد التي واصلنا فيها العمل  
بعون الله حتى وصلنا الى هذه المرحلة

نهدي هذا العمل إلى المعلم الأول والأخير الحبيب المصطفى (صلى الله عليه وسلم) سائلين  
المولى عز وجل أن يكون خالصا لوجهه الكريم ثم نتقدم بالشكر إلى أبائنا و أمهاتنا الأحياء  
منهم والأموات و إلى أساتذتنا الكرام الذين كانوا منارات تضيء دروبنا بالعلم وبالأخص  
البروفيسور سمير حنا الذي قام بالإشراف على هذا العمل ثم نتقدم بالشكر لكل من ساندنا ولو  
بابتسامة طيبة فنقول لهم تخوننا كل عبارات الشكر في تقديم ما يليق بكم ولن ننسى فضلكم  
علينا أبدا .

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## **Abstract :**

This project was made to purify drinking water by a system energized by solar energy, that is environmentally friendly .This project aims to serve people in rural areas, who can't be provided by electricity easily from the municipality. The process is to purify and disinfect water by flowing through four filtering stages, divided in two tanks processes in the sequence chlorination , carbon filter , ultraviolet disinfection and Ozone disinfection, after the system is energized by the solar system and the water is pumped from the well to the first container.

The project was simulated by LabVIEW ,showing the process in every stage on a computer screen .

- 1.1 Introduction
- 1.2 The Main Objectives
- 1.3 Challenges
- 1.4 Time Schedule
- 1.5 Economic Study

## **Chapter One: Introduction:**

### **1.1 Introduction:**

Clean water has been essential since humans were created, therefore humans have been checking waters purity, and recently technology has been developed for purifying water. So the main goal of this project is to purify water but instead of using fuel or dirty energy sources, it will be sourced by clean solar energy and using a clean energy source instead of conventional .

### **1.2 The main Objectives of the proposed project are :**

1. Decreasing the water pollution causes diseases to people by using clean energy that doesn't pollute the environment.
2. Producing such system in different scales, domestic and industrial.
3. Decreasing the cost of consumed power.
4. Can be used in rural areas far away from cities and municipality.
5. Decreasing maintenance costs where pumps sourced by solar energy need less maintenance than the ones sourced by diesel.

### **1.3 Challenges:**

- 1.Availability of the materials.
- 2.Eliminating all the microorganisms .
- 3.High expenses.
- 4.Calibrating the electrical devices and chemical materials.

### 1.4 Time Table:

The following table shows the time expected to finish the project:

Table 1.1 : Time Schedule

Week(Time)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Task																
1. Identification of project idea	■															
2. Drafting a Preliminary project proposal		■	■	■												
3. Introduction Chapter 1					■	■										
4. Mechanical Design							■	■	■							
5. Electrical Design								■	■	■						
6. Software Programming					■	■	■				■	■				
7. Controlling and interfacing design												■	■	■		
8. Reporting Documentation and financial model															■	■

### 1.5 Economic Study:

Table 1.2 : Economic Study

Name Of Element	Price(NIS)
Tanks	150
Electrical Valves	250
Filters	1000
Pump	170
PV System	1610
Sensors	350
Materials(wires , pipes , chemicals , Bases For Tanks)	700
Arduino Mega	80
Sum	4360

- 2.1 Chlorine Disinfection**
  - 2.1.1 Process Rules And Procedure**
  - 2.1.2 PH Adjustment**
  - 2.1.3 PH Process**
- 2.2 Second Stage :Carbon Filter**
  - 2.2.1 Carbon Filter Process Rules And Procedure**
- 2.3 Ultraviolet Disinfection**
  - 2.3.1 Work Principle**
  - 2.3.2 Ultraviolet Process Rules And Procedure**
- 2.4 Ozone Disinfection**
  - 2.4.1 Ozone Process Rules And Procedure**



## Chapter Two: Mechanical Design:

### 2.1 Overview:

The Water is Disinfected by four stages of filtering and disinfection steps in the following order as shown on the block diagram on figure (2.1) and show on figure(2.2) :

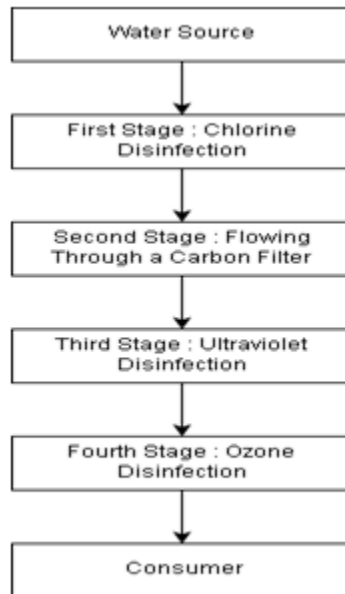


Figure2.1 : Mechanical Design Block Diagram

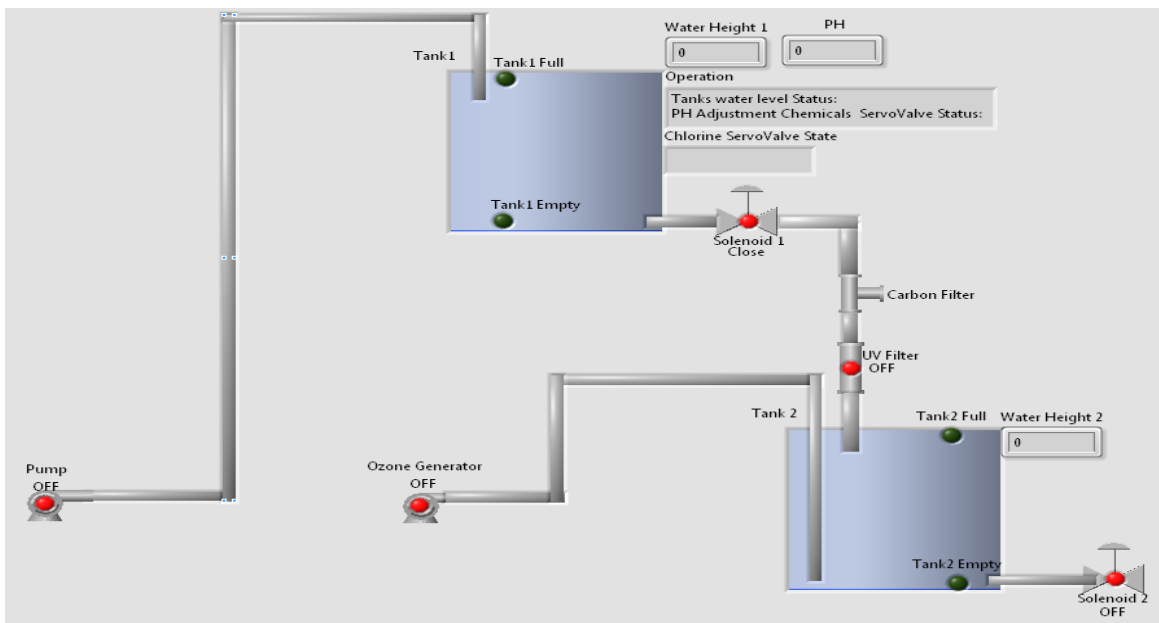


Figure2.2: Mechanical Design

## 2.2 Chlorine Disinfection:

Definition: Chlorination is the process of adding chlorine to drinking water to disinfect it and kill germs.

In this step of disinfection is done by adding Chlorine after adjusting PH with white vinegar or Soda Ash if needed as shown on figure(2.3)

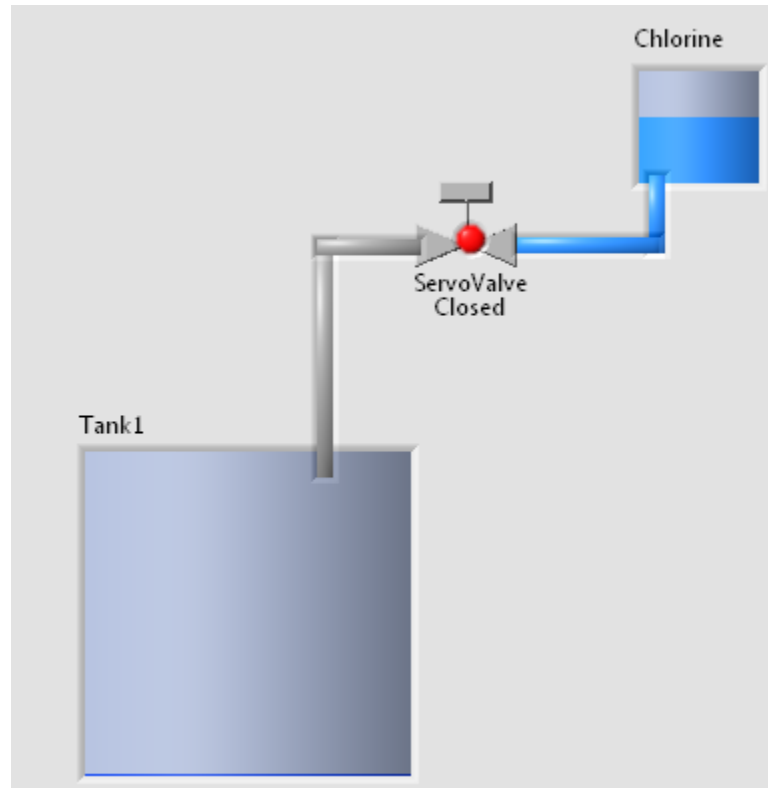


Figure2.3: Chlorine Disinfection

Chlorine disinfection as the following specifications[7]:

- Chlorinated water can taste and smell different than untreated water depending upon the water quality and amount of chlorine in the water.
- Chlorine is effective in killing bacteria, viruses, and other potentially harmful organisms in water.
- One disadvantage of chlorine is it can react with natural organic matter present in water to form potentially harmful disinfection byproducts.
- Water utilities sometimes use chlorine several times during treatment because the initial dose loses its effectiveness over time.

\*For more information check the appendix [A] and [B]

### 2.2.1 Process Rules And Procedure:

\*For effective disinfection with chlorine, the PH should preferably be less than 8.[12]

\*The water mustn't be cloudy therefore the process will not be active immediately until the water clears up.[8]

\*Water will be disinfected with chlorine by adding liquid household bleach, such as Clorox or Purex .

\*The amount of chlorine bleach that should be added is 110.93mg for every liter of water[9].

depending on our tank we will need:

$$Q = 11.039 \text{ gram of Clorox or Purex.}$$

$$\rightarrow \text{Amount of pure chlorine} = 5.548 * \text{Concentration} = 5.548 * 0.0525 = 6\text{mg} \dots(2.1)$$

Concentration or Contact Time(CT) Definition: Is the time needed to adequately disinfect water.

$$\text{Contact Time} = \frac{K}{\text{Chlorine concentration}} \dots(2.1)[10]$$

Table2.1: K value depending on PH and the waters temperature [10]

<b>K values to determine chlorine contact time</b>			
<i>Highest</i>	<i>Lowest Water Temperature (degrees F)</i>		
<i>pH</i>	<i>&gt; 50</i>	<i>45</i>	<i>&lt; 40</i>
<b>6.5</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>7.0</b>	<b>8</b>	<b>10</b>	<b>12</b>
<b>7.5</b>	<b>12</b>	<b>15</b>	<b>18</b>
<b>8.0</b>	<b>16</b>	<b>20</b>	<b>24</b>
<b>8.5</b>	<b>20</b>	<b>25</b>	<b>30</b>
<b>9.0</b>	<b>24</b>	<b>30</b>	<b>36</b>

### 2.2.2 PH Adjustment:

PH must be in the range of  $(6 \leq PH \leq 7.5)$ .

When the PH is more than 7 then it is acidic and when the PH is less than 7 it becomes alkaline .[11] and [12]

### 2.2.3 PH Process:

PH could be adjusted by injecting acid into alkaline water or injecting alkaline in acidic water where we will use Soda Ash as an alkaline and white vinegar as an acid. [11]

As shown on fig(2.4) below there two small tanks that provide soda ash and white vinegar when PH needs adjustment where the servo valves open by a signals generated from the Arduino Mega.

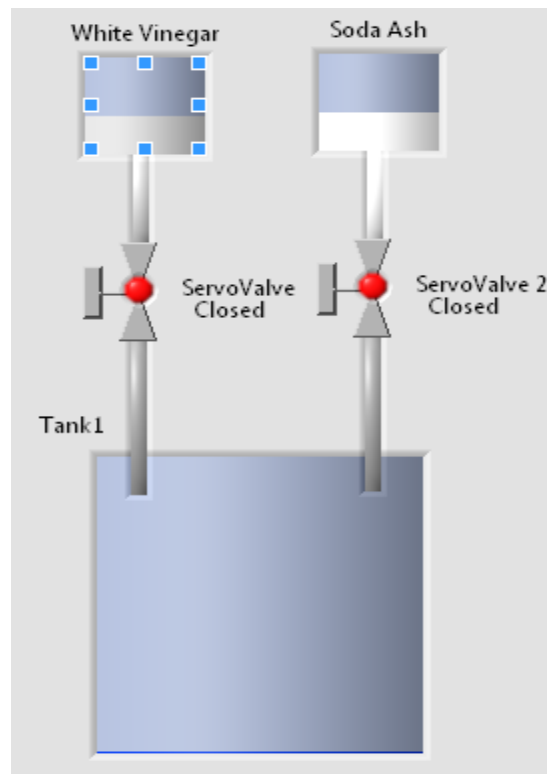


Figure2.4 : PH adjustment

1 part by weight of powder (Solute) + 9 parts by weight of water (Solvent)  
= 10 parts (Solutionweight) ... (2.2) [13]

Water density = 1kg/1liter.

Table2.2 : amount of soda ash that needs to be added depending on waters volume and the soda ashes density[13]

Solvent (Water)			5%	7.5%	10%	15%	20%	25%
litres	gallons	pounds	Pounds of Solute (Soda ash) to be added					
25	5.5	55	2.9	4.5	6.1	9.7	13.8	18.3
50	11.0	110	5.8	8.9	12.2	19.4	27.5	36.7
75	16.5	165	8.7	13.4	18.3	29.1	41.3	55.0
100	22.0	220	11.6	17.8	24.4	38.8	55.0	73.3
125	27.5	275	14.5	22.3	30.6	48.5	68.8	91.7
150	33.0	330	17.4	26.8	36.7	58.2	82.5	110.0
175	38.5	385	20.3	31.2	42.8	67.9	96.3	128.3
200	44.0	440	23.2	35.7	48.9	77.6	110.0	146.7

For more information check the appendix [C],[D]and[E]

### 2.3 Second Stage Carbon Filter:

Carbon Filtering is a method of filtering that uses a bed of activated carbon to remove contaminants and impurities , using chemical adsorption .

Carbon filters function:

Carbon filters remove the following [14],[15]:

- 1.Residual chlorine monochloramine sediments.
2. Contaminants and impurities.
- 3.Unwanted taste and odor caused by organic contaminants.
- 4.Doesnt remove minerals and salts.

### 2.3.1 Carbon Filter Process Rules And Procedure :

Carbon filtering has the following rules to be done [16].

\*Carbon filtrations pressure difference between the inlet and outlet raw water mustn't be more than 0.3 bar.

\*Carbon filters shouldn't be left inactive for more than three days.

\*The filter is applied between two pipes as seen on the figure(2.5):

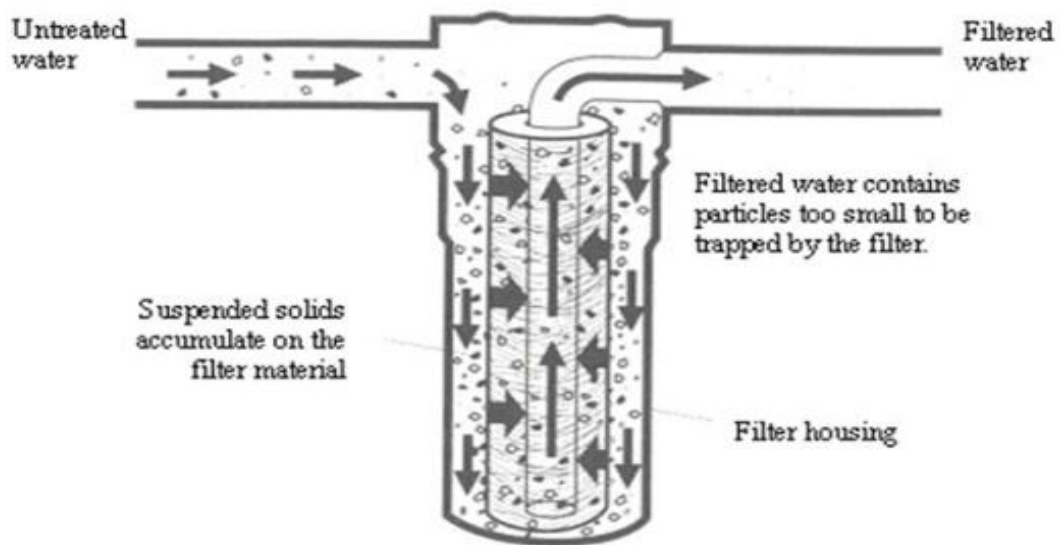


Figure2.5 : Carbon filters work principle

\*For more information look up appendix [F],[G]

## **2.4 Ultraviolet Disinfection:**

Ultraviolet rays definition: UV light is part of natural sunlight. It cannot be seen as UV light which is between visible light and x-rays.

Ultraviolet Disinfection's definition: the process of emitting UV light through the water , to disinfect it.

### **2.4.1 Work Principle:**

Ultraviolet has the following specifications [16] :

When UV light enters a microorganism its energy will damage the microorganism's cellular function by damaging the DNA so that it will not be able to grow or reproduce.

- \* UV light is normally effective against all viruses, bacteria and protozoa.
- \* Some microorganisms such as Cryptosporidium and Giardia have protective or thick cell walls that some low power UV light systems are not able to penetrate.
- \*Teflon and quartz glass tubes within the unit will require cleaning to remove algae and other deposits every period of time.

### **2.4.2 Ultraviolet Process Rules and Procedure:**

- \*The water must be clear and therefore a turbidity test will be done before starting the ultraviolet disinfection , if the turbidity is 1ntu or less then start the disinfection.[17]
- \*The bulb should be replaced depending on the manufacturers specified intervals usually about 9000 hours of work.[17]
- \*Skin and eyes must be protected from UV light radiations.[17]
- \*The U.S. Department of Health and Human Services has established a minimum exposure of 16,000  $\mu\text{watt-sec/cm}^2$  for UV disinfection systems.[17]
- \*The UV light bulb is usually applied vertical to the water.[17]

As Shown on fig(2.6) it can be seen how the water flows through the ultraviolet tube for disinfection.

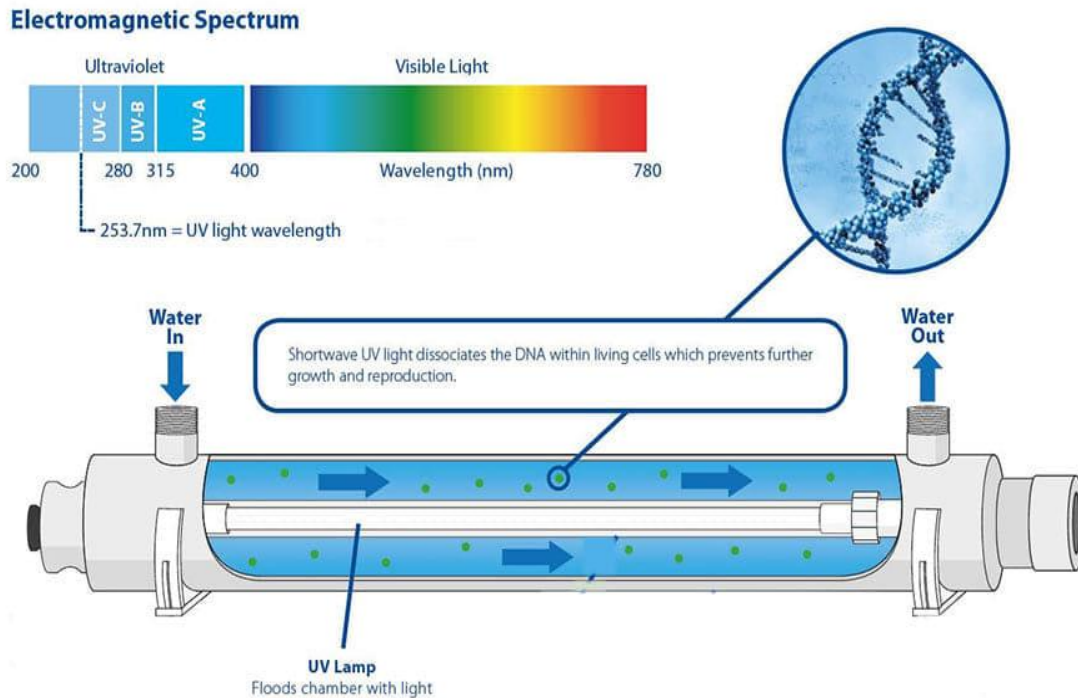


Figure2.6 : the work principle of ultraviolet disinfection

For more information look up appendix [H],[I]

## 2.5 Ozone Disinfection:

Definition: Ozone is an unstable gas comprising of three oxygen atoms, it is colorless and has an odor similar to the air after a major thunderstorm.

Ozone disinfection affects the process by [19]:

\*Ozone degrades back to Oxygen and a free radical in the operation where the radical is highly reactive and short lived , under normal conditions radicals only survive for milliseconds.

\*.Ozone has greater disinfection effectiveness against bacteria and viruses compared to chlorination.

\*Oxidizing properties can also reduce concentration of Iron , Manganese , Sulfur and reduce or eliminate taste and odor problems.

\*Oxygen is formed into ozone by the use of energy of an electric discharge field.



### 2.5.1 Ozone Process Rules And Procedure:

\*Water temperature should be between (10-35) C ° .[20]

\*Turbidity should be between (0 - 1)NTU.[20]

\*PH must be between (6.5-8.5).[20]

\*Ozone disinfects water by being added and making bubble contact during time between 10 to 12 minutes and concentration of 0.04-0.3mg per liter.[21]

The ozone needed for 100 liters of water is less than and more than according to the following equations :

$$\text{Maximum amount of ozone} = 0.3\text{mg ozone} * 100\text{liter} = 30\text{mg ozone}$$

$$\text{Minimum amount of ozone} = 0.04\text{mg ozone} * 100\text{liter} = 4\text{mg ozone}$$

If the ozone generator is set to compress 100mg/hour then the amount of ozone per liter pumped equals :

$$\frac{\text{Compressed Ozone}}{10\text{min}} = \frac{100\text{mg}}{\text{hr}} * \frac{\text{hr}}{60\text{min}} * 10\text{min} = 16.665\text{mg ozone}$$

Depending on the data given from the ozone generator shown on fig (2.7) and fig(2.8) is used for purifying the water:



Figure2.7 Ozone generator

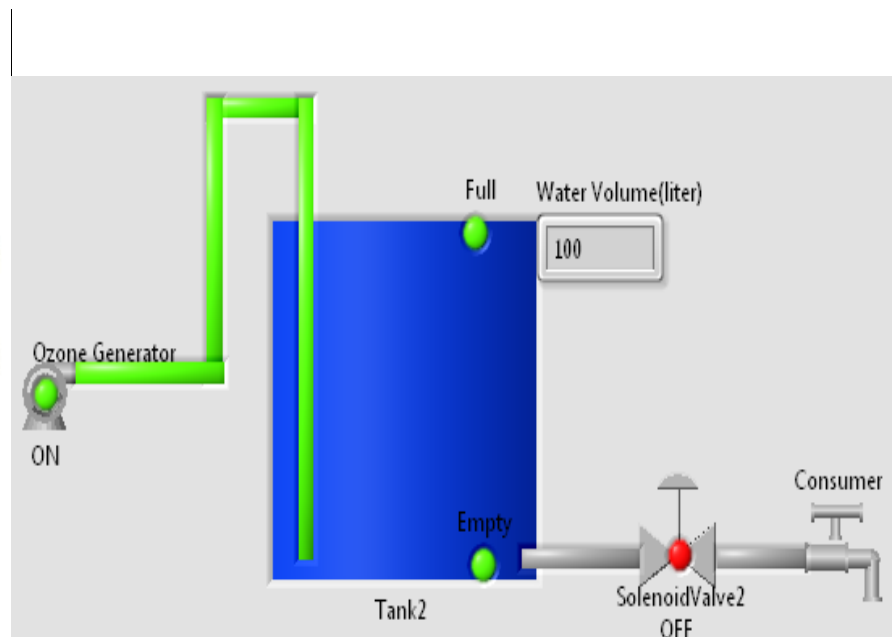


Figure2.8 Ozone Disinfection Process

For more information look up appendix [J]

- 3.1 Whole System Design**
  - 3.1.1 Arduino Input Circuit Design**
  - 3.1.2 Arduino Output Circuit Design**
- 3.2 Off-Grid Solar PV System Design**
  - 3.2.1 Auxillary Energy Resources**
- 3.3 Components Of Off-Gird PV System**
  - 3.3.1 PV Array**
  - 3.3.2 Types Of Solar PV Modules**
  - 3.3.3 DC-AC Inverter**
  - 3.3.4 Charge Controller**
  - 3.3.5 Battery Bank**
    - 3.3.5.1 Energy Storage Capacity, Days of Anatomy and the DOD**
- 3.4 PV System Design And Configuration**
  - 3.4.1 Tilt Angle**
  - 3.4.2 Location**
- 3.5 Power Demand Of the Project**
  - 3.5.1 AC Power Calculations**
  - 3.5.2 DC Power Calculations**
  - 3.5.3 Battery Bank Sizing And Cost Estimate**
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  - 3.5.5 Charge Controller Calculations**
  - 3.5.6 Inverter Calculations**
  - 3.5.7 Wiring Sizing**
- 3.6 Protection Design**
- 3.7 PV System Cost**
- 3.8 Time Needed To Empty The First Tank Into The Second Tank**

# Chapter Three: Electrical Design:

## 3.1 The Whole System Design:

The general electrical design is shown on the figure(3.1) :

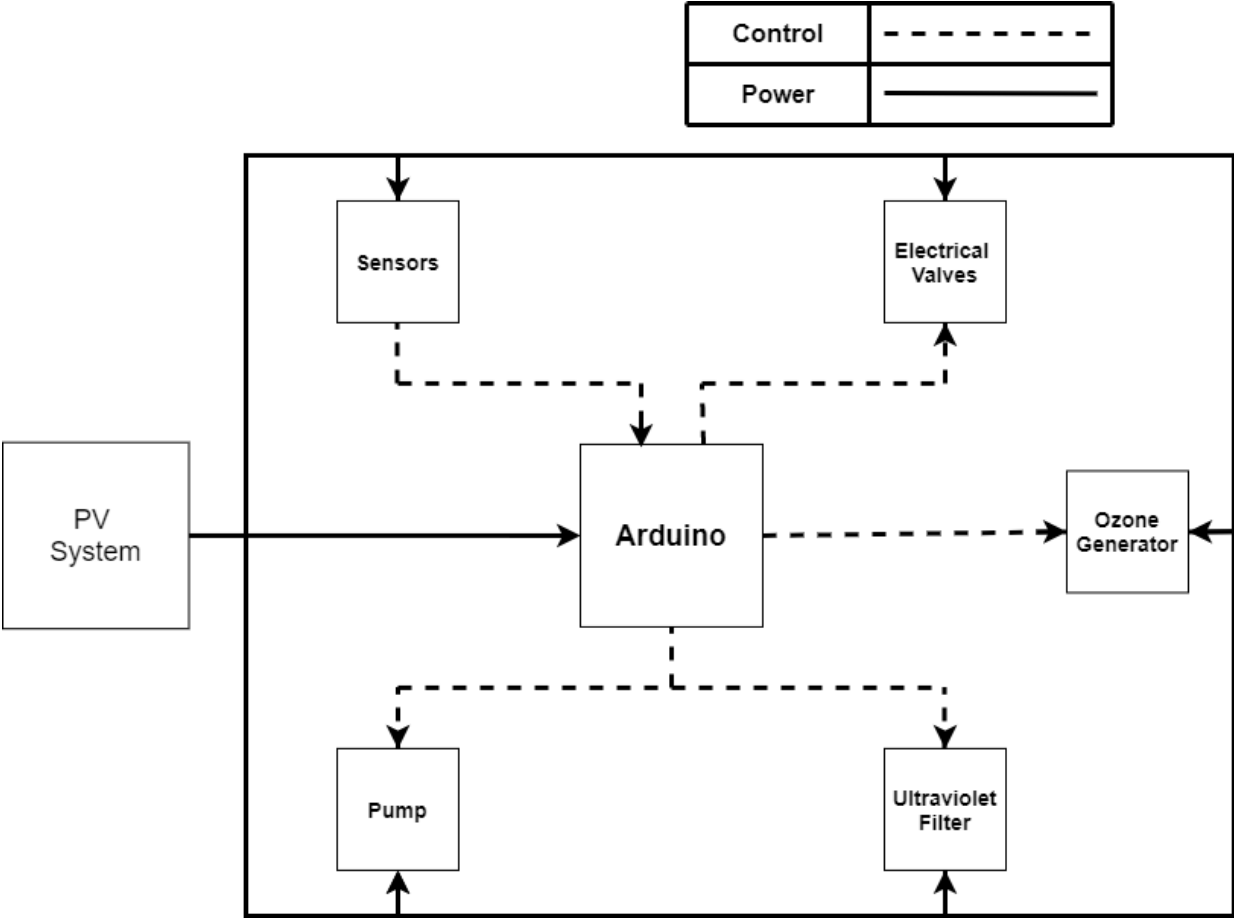


Figure 3.1 : Complete system design

### 3.1.1 Arduino Input Circuit Design:

The Arduino receives data as electrical quantities from the sensors and is connected as shown on figure(3.2).

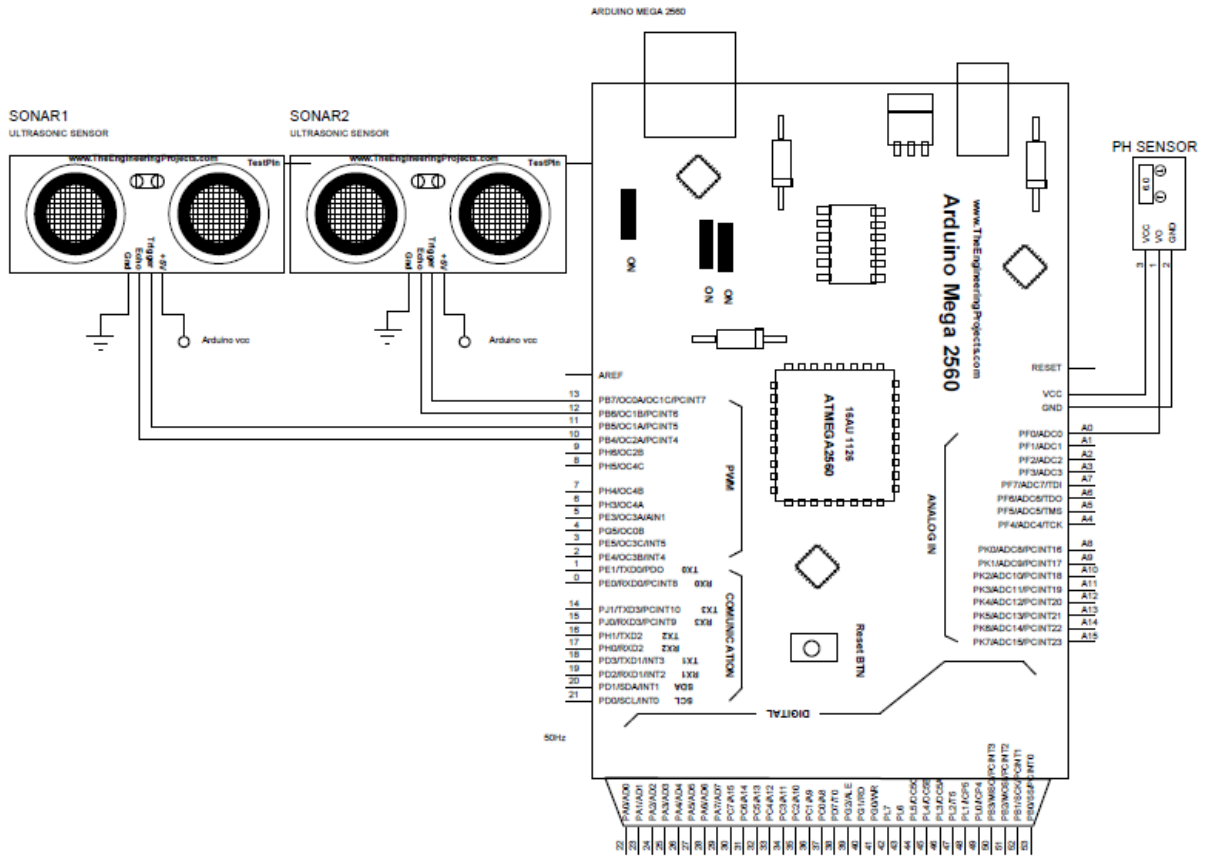


Figure3.2 Arduino Input Connection Design

### 3.1.2 Arduino Output Circuit Design:

The Arduino generates signals as electrical quantities to control the devices and is connected as shown on figure(3.3).

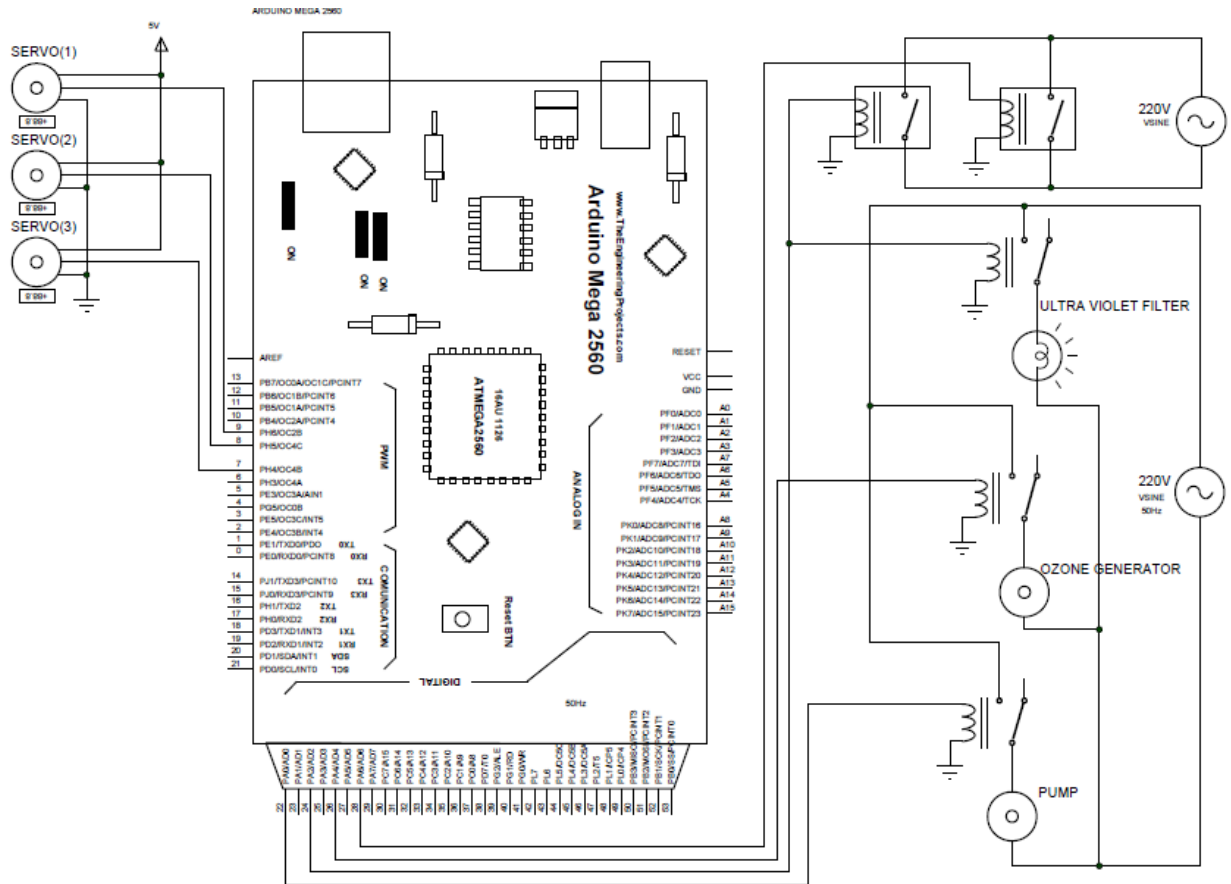
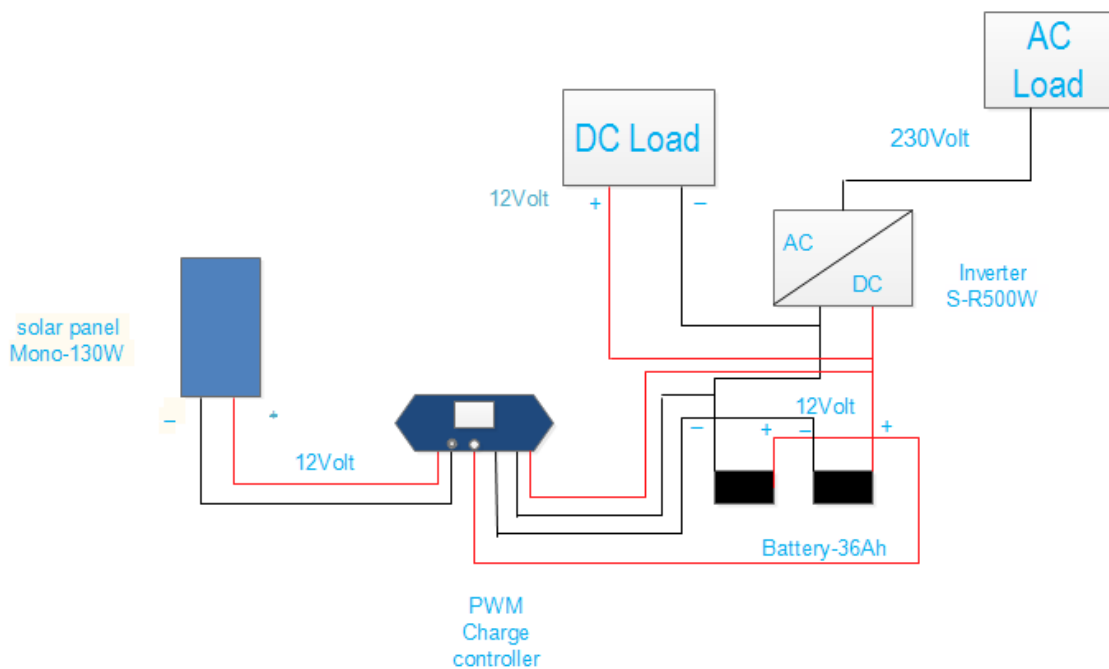


Figure3.3 Arduino Output Connection Design

### 3.2 Off-Grid Solar PV System Design:

One might encounter such solar system when there is no grid in such a rural area or even when the utility power pricing is quite high. Here, the solar panels become the utility company and generate the needed energy by one's home or any energy dependent system [18], [6]. There may be no option other than to go with an off-grid solar system. Off-Grid systems require more care and maintenance but can give a strong sense of independence, so one is no longer being subjected to the risk of a loss of power from the utility grid. Off-Grid solar systems where the solar energy is generated and consumed in the same place meaning it does not interact with the main grid at all. Figure (3.4) [24], [23] shows a simple schematic for the Off-Grid solar PV system.

Figure 3.4 Off –Grid PV System



#### 3.2.1 Auxiliary Energy Resources :

An assistant/ auxiliary energy resource is a diesel generator or other renewable sources that provision with the required power when the off-grid PV framework is incapable for providing the required power shown on figure(3.5). [24]

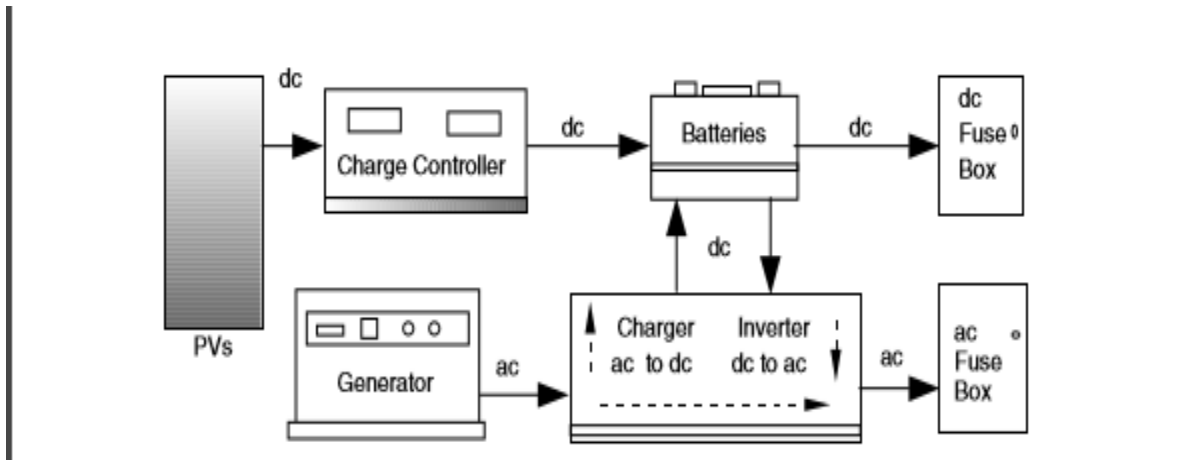


Figure3.5: A Stand-Alone System With Backup Generator And Separate Outputs For DC And AC Loads.

### 3.3 Components Of Off-Grid PV System :

#### 3.3.1 PV Array:

A solar PV Array is comprised of PV modules, which are fixed accumulations of PV Cells. A PV array is the entire electric power creating unit. It comprises of any number of PV modules. The most crucial segment of any solar PV system is the PV module, which are made out of various interconnected solar cells. Solar PV modules are associated together into strings to meet different vitality needs, as appeared on figure (3.6). The solar system is associated with an inverter that changes over the Direct Current (DC) created by the sun powered PV cluster into Alternating Current (AC) perfect with the power provided from the lattice. Air conditioning yield from the inverter is associated with the home's electrical board or utility meter, contingent upon the design.[24]

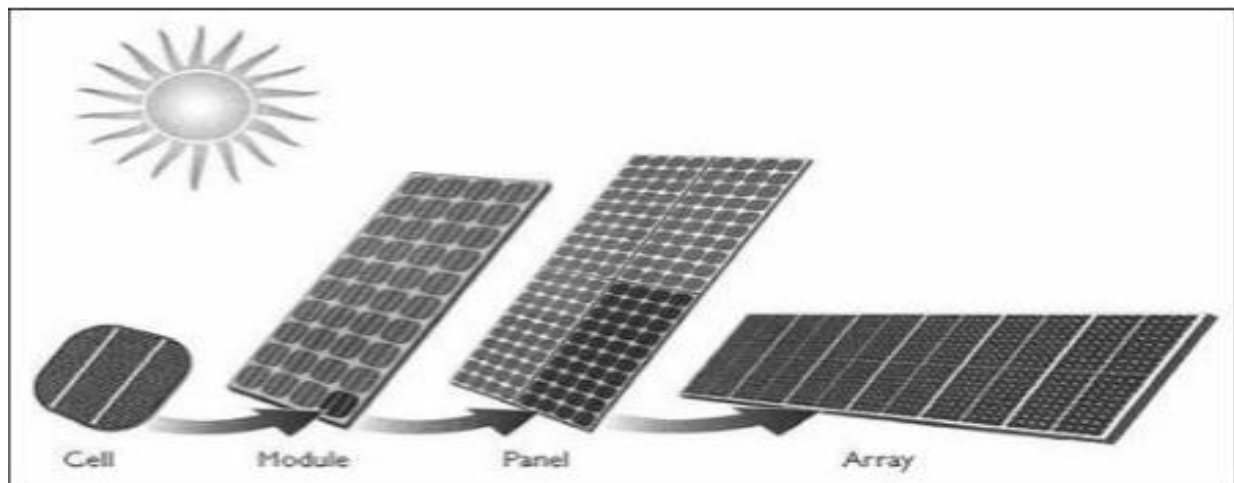


Figure3.6 The Relationship Among Cell, Module And Array

### 3.3.2 Types of Solar PV Modules :

**1. Monocrystalline Silicon Modules:** They offer high efficiency (15-20) % and good heat tolerance characteristics in a small footprint but it is quite expensive.

**2. Polycrystalline Silicon Modules :**They offer less efficiency than the monocrystalline modules (13-16) %. Moreover, the process of manufacturing them is simpler and cheaper and also less heat tolerance characteristics in a small footprint.

**3. Thin film:** They offer an efficiency of (4-12) % and heat tolerance characteristics that are less than the crystalline modules. Also, they are available in a price that are slightly higher than the polycrystalline and lower than the monocrystalline modules, as shown on figure(3.7) .[24]

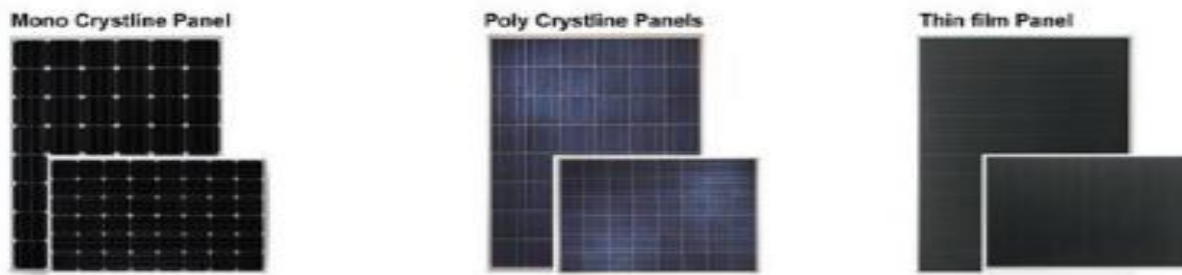


Figure3.7: Types Of PV Modules

### 3.3.3 DC-AC inverter:

Is an exceptional kind of power inverter that transforms direct current (DC) into alternating current (AC) and sustains it into an existing electric grid in grid-connected solar PV systems and to the AC electric appliances in the case of an off-grid solar PV system as shown on figure (3.8). It Changes the DC output yield of the solar PV panels or into an AC current for AC-functioning electric appliances.[24]



Figure3.8 Power Inverter



### 3.3.4 Charge Controller:

Directs the voltage and current originating from the PV panels going to the battery and prevents battery overcharging and prolongs the battery life span.

A charge controller decides how much current ought to be injected into the batteries for its most ideal electric performance. As it decides the efficiency of the whole solar PV system, it affects the operating life of the batteries and it is considered to be a vital segment in the solar PV system. There are several types of charge controllers being manufactured but the most two common types are the PWM (Pulse with Modulation) fig (3.9) and MPPT (Maximum Power Point Tracker) simultaneously. These two kinds are commonly used in nowadays solar PV systems. Both adjust charging rates depending on the battery's charge level to allow charging closer to the battery's maximum capacity as well as monitor battery temperature to prevent overheating which is preferable in order to sustain the battery bank life span.[24]



Figure3.9 :PWM Charge Controller.

### 3.3.5 Battery Bank:

It stores electric energy for providing to electrical devices when there is a need. There might be periods when there is no daylight. Night times, evenings and shady days are cases of such circumstances outside our ability to control. Keeping in mind the end goal to give power amid these periods, abundance vitality, within the day, is put away energy in these battery banks and is utilized to power loads at whatever point required. Normally a battery bank consists of number of batteries which are wired in series or parallel according to needed battery bank by the solar PV system , look up the figure(3.10).[24]

### 3.3.5.1 Energy Storage Capacity, Days of Autonomy and the DOD:

To store solar energy when there is an overabundance is accessible by the solar PV system in order to supply it when energy is required. Generally, the term of days of autonomy refers to the number of days that the whole solar system can function properly without the feed by the solar PV panels and it is normally lays somewhere in the region between (2-5) days depending on the system configuration energy demand and the solar system location, and climate. It is also worth mention that the capacity of the energy storage bank is connected to the DOD (Depth of discharge) which means the degree which the battery is going to be discharged in relative to its total capacity. For example, a 36 Ah battery with 30% DOD exhibits a 25.2 Ah capacity remaining of the stored energy in it. [24]



Figure3.10 :Battery Bank

## 3.4 PV System Design and Configuration:

### 3.4.1 Tilt Angle :

The tilt angle of a photovoltaic array is the key to an optimum energy yield. Solar panels are most efficient when they are perpendicular to the sun's ray. In Hebron the optimum tilt angle is 30° for a fixed system, in summer as shown on figure(3.11).[28]

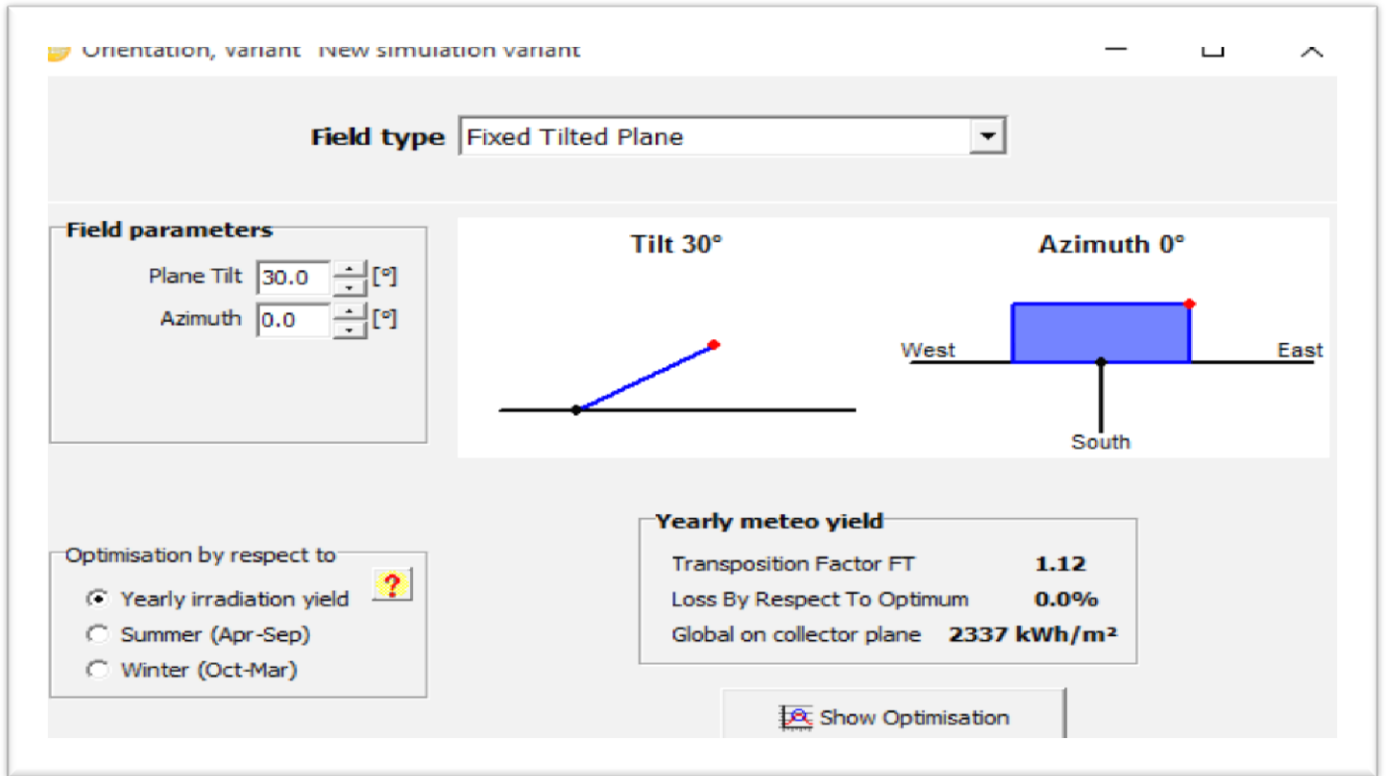


Figure3.11: Tilt Angle In Hebron PV System Program.

### 3.4.2 Location:

The system will be installed in Hebron, Palestine 31.59 ° N, 35.8 ° E. The entire system was constructed on a flat, elevated, empty, and not shaded plot. The panel was placed in a southern direction, with no shading or shading throughout the year as shown on figure(3.12). [28]

PVSYST V6.70		03/12/19		Page 1/4	
<b>Stand Alone System: Simulation parameters</b>					
<b>Project :</b>	<b>New Project</b>				
<b>Geographical Site</b>	<b>Hebron</b>		<b>Country</b>	<b>Israel</b>	
<b>Situation</b>	<b>Latitude</b>	31.59° N	<b>Longitude</b>	35.80° E	
<b>Time defined as</b>	<b>Legal Time</b>	Time zone UT+2	<b>Altitude</b>	930 m	
<b>Meteo data:</b>	<b>Albedo</b>	0.20	<b>Hebron</b> Meteonorm 7.1 (1990-2004), Sat=100% - Synthetic		

Figure3.12: location PV System Program

### 3.5 Power Demand Of The Project:

The daily load profiles were determined by calculating the power demand (W.h/day) for all load types in the project. The estimated daily energy demand is given in Table 3.1 below. The appliances used in the project are AC and DC loads

Table3.1: Load Profile of the Appliances

Appliance	Quantity	Power Rating (Watt)	Power consumption	Hours of use per Day	Energy per Day
servo motor	2	10.8	10.8	0.133	1.44
servo motor	1	5.4	5.4	0.0166	0.089
Ultrasonic sensor	2	0.02	0.02	24	0.48
Ozone generator	1	18	18	0.3	5.4
Arduino mega	1	0.430	0.430	24	10.32
Solenoid valve	2	14.72	14.72	0.083	0.368
PH sensor	1	0.72	0.72	24	17.28
Pump	1	193.6	193.6	0.25	29.04
Charge controller	1	2.4	2.4	24	57.6
Ultraviolet	1	12	12	0.083	0.0996
<b>Daily watt power</b>			<b>258.09</b>		
<b>Total energy demand per day</b>					<b>122.116wh/day</b>

### 3.5.1 AC power calculation:

Figure(3.13) shows the pump design that was used in the calculations:

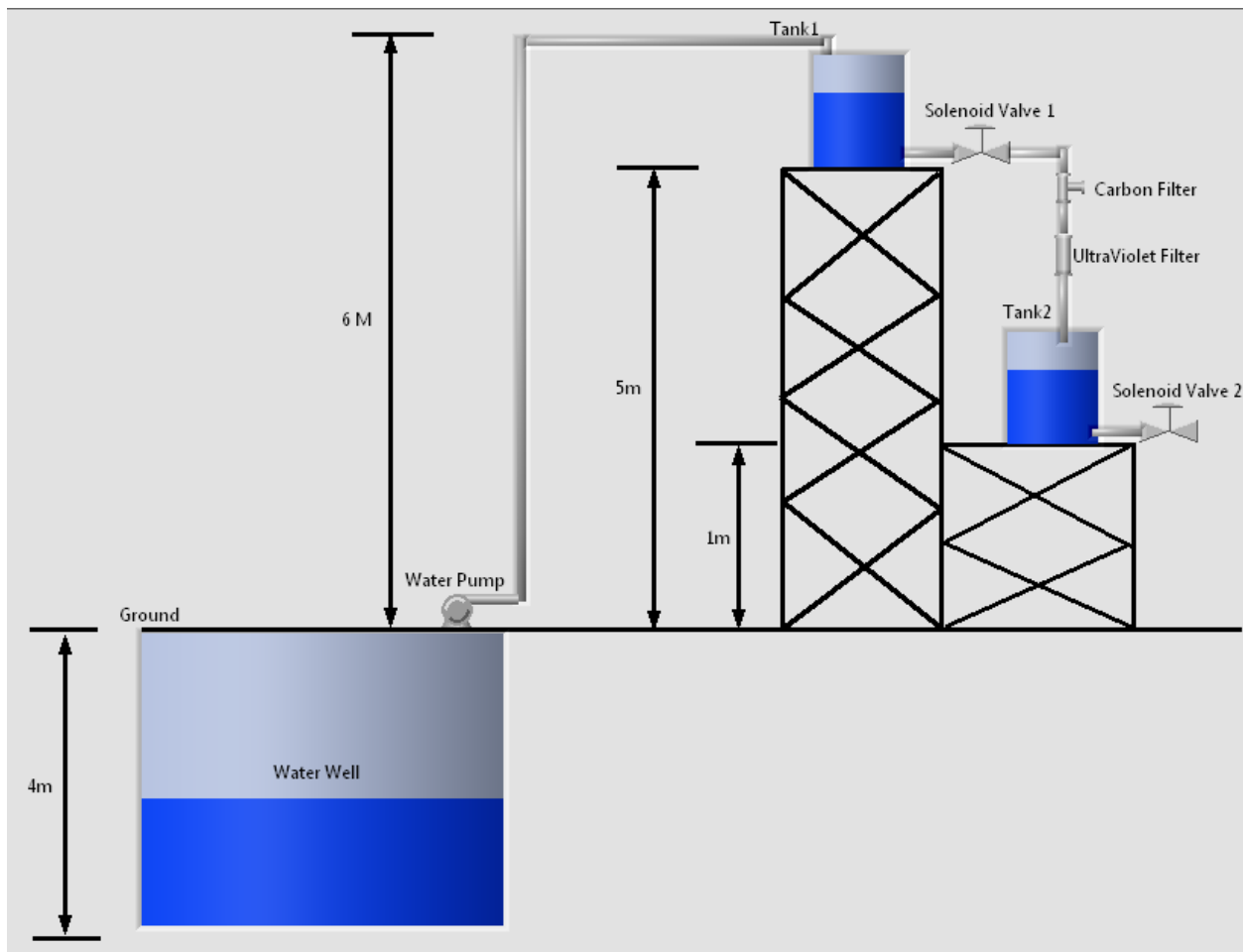


Figure3.13 :Pump Design

#### Pump Calculation:

$$Time = \frac{Q_{tank}}{Q_{flow}} \quad (3.1)$$

$$Time = \frac{100l}{12l} * 1min = 8.3 \approx 9min$$

Where:

$Q_{tank}$  : Daily water demand in liter gallons.

$Q_{flow}$  : Water flow rate the pump provide found from figure(3.14) .

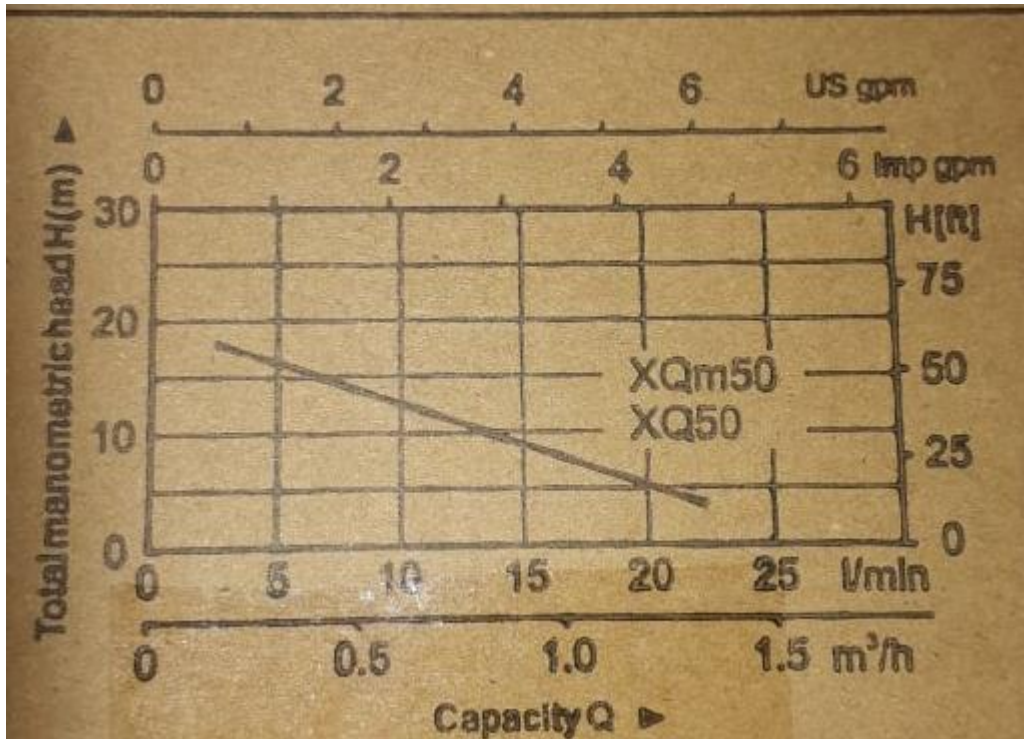


Figure 3.14 Flow Rate Per Minute

\*For more information check the appendix [W]

The hydraulic power is determined according to eq.(2), [4]:

$$P_{hydraulic} = g \left( \frac{m}{s^2} \right) * H(m) * Q \left( \frac{L}{s} \right) \quad (3.2)$$

Where:

g : gravity constant 9.81 m/s .

$P_{hydraulic}$  : Hydraulic power.

H: is the static head in meter.

Q: Flow rate.

Substituting in eq(3.2) :

$$P_{hydraulic} = 9.81 \left( \frac{m}{s^2} \right) * 10 (m) * \frac{100}{9 \text{ min} * \frac{60 \text{ sec}}{\text{min}}} = 18.2 \text{ Watt}$$

$$P_{input} = I * V * PF \quad (3.3)$$

Where:

V: Voltage

I: Required motor current

PF: Power factor

After selecting the pump and the motor driving this pump look at the motor datasheet.....Efficiency, PF, I, V, IP

Substitute in eq(3.2)

$$P_{input} = 220(V) * 1.1(A) * 0.8 = 193.6 \text{ Watt}$$

$$\eta_{motor} = \frac{\text{(out put power)}}{\text{(Input power)}} \quad (3.4)$$

Substituting in eq(3.4):

$$\eta_{motor} = \frac{P_{out}}{P_{in}} = \frac{111 \text{ w}}{193.6 \text{ w}} = 57.3\%$$

[21]

**solenoid valve:**

$$P_{sol} = I * V = 0.032(A) * 230(V) = 7.4 \text{ Watt} \quad (3.5)$$

Where I = 0.032 A, look up appendix [P]

**Ultraviolet Sensor:**

$$P_{UV} = I * V = 0.0545(A) * 220(V) = 12 \text{ Watt}$$

Where I = 0.0545 A, look up appendix [X]

**Ozone generator:**

$$P_{sol} = I * V = 0.0818(A) * 220(V) = 18 \text{ Watt}$$

Where I = 0.0818A, look up appendix [M]

### 3.5.2Dc power calculation:

#### Servo motor:

$$P_{servo} = I * V = 0.9(A) * 6(V) = 5.4Watt$$

Where I = 0.9A, look up appendix [N]

#### Ultrasonic sensor:

$$P_{Ultra\ Sonic} = I * V = 0.01(A) * 5(V) = 0.05\ Watt$$

Where I = 0.01 A, look up appendix [x]

#### PH sensor:

$$P_{PH\ Sensor} = I * V = 0.06(A) * 12(V) = 0.72\ Watt$$

Where I = 0.06 A, look up appendix [K]

#### Charge controller:

$$P_{Charge\ Controller} = I * V = 0.2(A) * 12(V) = 2.4Watt$$

Where I = 0.2 A, look up appendix [y]

#### Arduino Mega:

$$P_{Arduino\ Mega} = 0.43\ Watt$$

Where P= 0.43W, look up appendix [O]



System Duty Operation:

The proposed system has the duty operation cycle stated in table( 3.2).

Table3.2:The Duty Operation Cycle

Time(hour)	9:00- am 9:09	9:9- am 9:13	9:13- am 9:17	9:17- am 9:22	9:18- am 9:22	9:22- am 9:39	9:39- am 9:41	9:41- am 9:50	4:00	10:00	4:00	8:00
System Component												
Pump												
Arduino mega												
Ultrasonic sensor												
PH sensor												
Servo motor												
Servo motor												
Solenoid valve												
Ultraviolet												
Ozone generator												
Solenoid valve												
Charge controller												

Substituting in the equation (3.6) ,[4]

$$Total\ dc\ load\ \left(\frac{wh}{day}\right) = dc\ load\ \left(\frac{w.h}{day}\right) + \frac{ac\ load\ \left(\frac{wh}{day}\right)}{inverter\ efficiency}$$

$$Ed_{total} = 87.2\ \left(\frac{wh}{day}\right) + \frac{36.808\ \left(\frac{w.h}{day}\right)}{0.95} = 124\ \frac{w.h}{day}$$

### 3.5.3 Battery Bank Sizing and cost Estimate:

#### System Voltage:

Table3.3: selected voltage system.

Maximum ac power	System dc voltage
<1200W	12V
1200W-2400W	24V
2400W-2800W	48V

Selected system <1200→12 volt

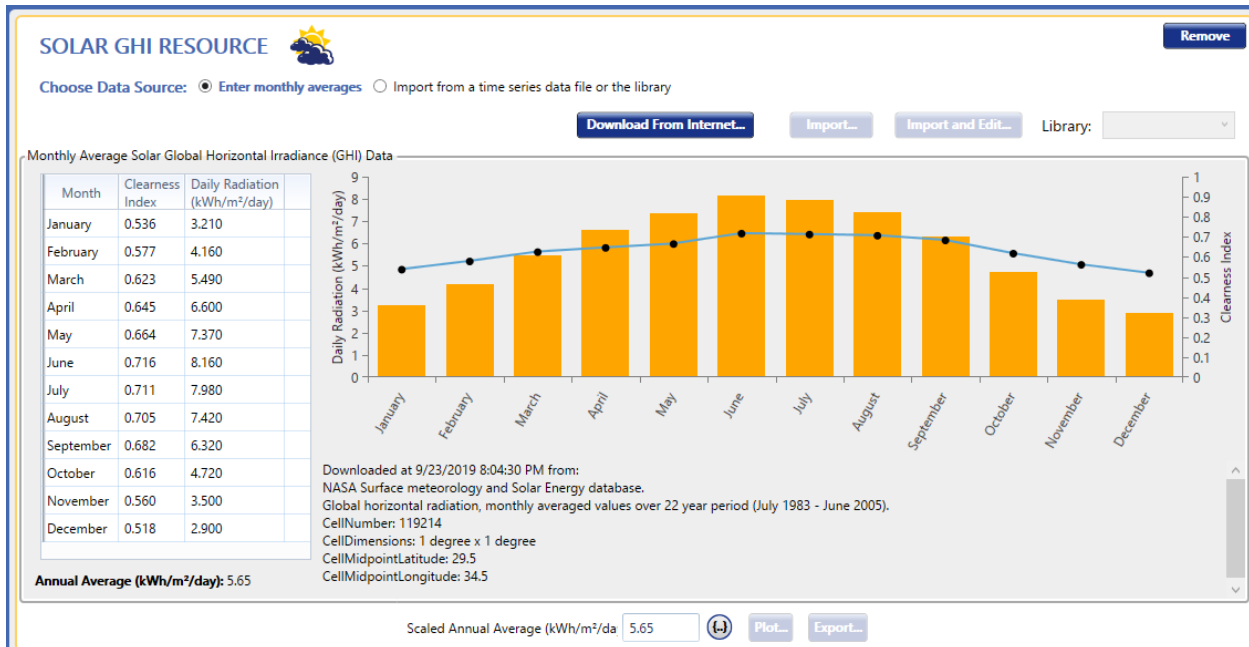


Figure3.15: Daily Irradiation

According to equation(3.7),[4]:

$$Storage\ days\ (95\%) \approx 9.43 - 1.9(Peak\ Sun\ hours) + 0.11(Peak\ Sun\ hours)^2 \quad (3.7)$$

The worst days in a month in December:

$$S.d = 9.4 - (1.9 * 2.9) + 0.11*(2.9)^2 = 3 \text{ days}$$

According to calculated total DC power, a( Sigma power systems-12v-18Ah )Battery with the following main data :

Table3.4:Datasheet Sigma Battery.

Required Information	Capacity	Dimmession
capacity of selected battery Cb_(Ah)	<b>18</b>	<b>A.h</b>
voltage of selected battery ( Vb)	<b>12</b>	<b>Volt</b>
Number of Days of Autonomy (Dauto)	<b>1</b>	<b>Days</b>
depth of discharge(DOD)	<b>30</b>	<b>%</b>
Battery efficiency	<b>95%</b>	<b>%</b>
Cost of battery (C_b) \$/Ah	<b>1.65</b>	<b>\$/Ah</b>
Estimated Energy Storage (Eest)	<b>124</b>	<b>W.h</b>
Safe Energy Storage (Esafe)	<b>413.3</b>	<b>W.h</b>
Total Capacity of Battery Bank (Ctb)	<b>34.4</b>	<b>A.h</b>
Total Number of Batteries in Bank(Ntb)	<b>2</b>	<b>batteries</b>
Number of Batteries in Series (Nsb)	<b>1</b>	<b>batteries</b>
Number of Batteries in Parallel (Npb)	<b>2</b>	<b>batteries</b>
Cost of Battery Bank in KL(Bbcost)	<b>55</b>	<b>\$</b>

\*For more information check the appendix [R] .

Can be determined according to the equations [4] :

$$E_{est} = E_D \times D_{out} = 124 \frac{w.h}{day} * 1 \text{ day} = 124 w.h \quad (3.8)$$

$$E_{safe} = \frac{E_{est}}{D_{disch}} = \frac{124}{0.30} = 4.133 A.h \quad (3.9)$$

$$C_{tb} = \frac{E_{safe}}{V_b} = \frac{413.3}{12} = 34.4 A.h \quad (3.10)$$

$$N_{tb} = \frac{C_{tb}}{C_b} = \frac{34.4}{18} = 1.9 \approx 2 \text{ batteries} \quad (3.11)$$

$$N_{sb} = \frac{V_{dc}}{V_b} = \frac{12}{12} = 1 \text{ batteries} \quad (3.12)$$

$$N_{pb} = \frac{N_b}{N_{sb}} = \frac{2}{1} = 2 \text{ batteries} \quad (3.13)$$

$$C_B = (1.6 \frac{\$}{Ah}) \times A \cdot h_{tot} = (1.6 * 34.4) = 55\$ \quad (3.14)$$

### 3.5.4 PV Array Sizing and Cost Estimate:

According to calculated total DC power, a ( Monocrystalline ) Panel with the following main data:

Table 3.5: Data sheet Panel.

<b>Required Information</b>			
Nominal rated PV module output		<b>130</b>	<b>W</b>
PV module max power voltage Vmp		<b>18.9</b>	<b>Volt</b>
PV module max power current (Imp)		<b>6.88</b>	<b>Amp</b>
PV module short circuit current (Isc)		<b>7.43</b>	<b>Amp</b>
average sun hours (Tsh)		<b>5.65</b>	<b>Hour</b>
System Voltage (Vsys)		<b>12</b>	<b>Volt</b>
Cost of Solar Module (C_pv) \$/w		<b>2</b>	<b>\$/W</b>
<b>PV Array Sizing and Cost Estimate</b>			
Parameter Being Determined	Computed Parameter Value		
Required Daily Energy Demand (Erd)		<b>146.2</b>	<b>Wh/Day</b>
Average Peak Power (Pave, peak)		<b>25.9</b>	<b>W</b>
Total dc Current (Idc)		<b>2.2</b>	<b>Amp</b>
Number of Series Modules (Nsm)		<b>1</b>	<b>No series</b>
Number of Parallel Modules (Npm)		<b>1</b>	<b>No parallel</b>
Total Number of Modules (Ntm)		<b>1</b>	<b>No Array</b>
Total Cost of Array in KL (Acost)		<b>67</b>	<b>\$</b>

\*For more information check the appendix [S]

According to the following equations [4]:

$$E_{rd} = \frac{E_d}{\eta_b \times \eta_{inv} \times \eta_c} = \frac{124}{0.95 \times 0.95 \times 0.94} = 146.2 \frac{w.h}{day} \quad (3.15)$$

$$P_{avg,peak} = \frac{E_{rd}}{T_{sh}} = \frac{146.2}{5.65} = 25.9 \text{ Watt} \quad (3.16)$$

$$I_{dc} = \frac{P_{avg,peak}}{V_{dc}} = \frac{25.9}{12} = 2.2 \text{ A} \quad (3.17)$$

$$N_{sm} = \frac{V_{dc}}{V_{rm}} = \frac{12}{12} = 1 \quad (3.18)$$

$$N_{pm} = \frac{I_{dc}}{I_{rm}} = \frac{2.2}{2.2} = 1 \quad (3.19)$$

$$N_{tm} = N_{sm} \times N_{pm} = 1 \times 1 = 1 \quad (3.20)$$

$$C_{pv} = (0.8 \frac{\$}{W}) * PV_{peak \text{ power}} * N_m = 0.8 * 130 * 1 = 104\$ \quad (3.21)$$

### 3.5.5 Charge Controller Calculations:

According to calculated total DC power, a ( PWM -5024) Charge Controller with the following main data :

Table3.6: Datasheet Charge Controller.

<b>Required Information</b>			
Charge Controller efficiency		<b>94%</b>	<b>%</b>
voltage of charge controller (V <sub>cc</sub> )		<b>12</b>	<b>Volt</b>
charge controller current (I <sub>cc</sub> )		<b>50</b>	<b>Amp</b>
Safety factor (F <sub>safe</sub> )		<b>1.01</b>	<b>non</b>
Cost of charge controller (C <sub>c</sub> )/A		<b>5</b>	<b>\$/A</b>
<b>Charge Controller Sizing and Cost Estimate</b>			
Parameter Being Determined	Computed Parameter Value		
Charge Controller Current (I <sub>rcc</sub> )		<b>7.5043</b>	<b>Amp</b>
Number of Charge Controllers (N <sub>cc</sub> )		<b>1</b>	<b>charger</b>
Max. voltage of PV array panel		<b>18</b>	<b>Volt</b>
Min . voltage of PV array panel		<b>13.3</b>	<b>Volt</b>
Cost of charge controller in KL (C <sub>c</sub> )		<b>22.5</b>	<b>\$</b>

\*For more information check the appendix [Y] .

Substituting in the following equations [4]:

$$I = I_{sc} \times N_p \times F_{safe} = 7.43 \times 1 \times 1.01 = 7.5A \quad (3.22)$$

$$N_{controller} = \frac{I}{amp \text{ each contrller}} = \frac{7.5}{50} = 0.2 \approx 1 \quad (3.23)$$

$$V_{pv} = V_m \times 0.95 \times N_s = 18.9 \times 0.95 \times 1 = 18 \text{ Volt} \quad (3.24)$$

$$V''_{pv} = \frac{C_{c_{volt}}}{\eta_{cable}} = \frac{12}{0.90} = 13.3 \text{ Volt} \quad (3.25)$$

$$C_c = (3 \frac{\$}{A}) * I_{Controller} * N_{Controller} = 3 * 7.5 * 1 = 22.5\$ \quad (3.26)$$

### 3.5.6 Inverter Calculations:

According to calculated total DC power, a (SR-500-S) Inverter with the following main data :

Table 3.7: Datasheet Inverter:

Required Information		
Inverter efficiency $\eta$	<b>95%</b>	<b>%</b>
DC voltage input	<b>12</b>	<b>Volt</b>
Inverter Output Voltage Vac	<b>230</b>	<b>Volt</b>
Power rating of Inverter Pi	<b>500</b>	<b>Watt</b>
Power Factor pf	<b>0.8</b>	
Cost of inverter (C_inv) \$/W	<b>0.4</b>	<b>\$/A</b>
Inverter Sizing Procedure and Cost Estimate		
Parameter Being Determined	Computed Parameter Value	
Total Inverter Power (Pi)	<b>43.9</b>	<b>Watt</b>
apparent power of the inverter S	<b>54.9</b>	<b>VA</b>
Current at Inverter Output	<b>4.8</b>	<b>Amp</b>
Cost of Inverter in KL(Icost)	<b>200</b>	<b>\$</b>

\*For more information check the appendix [L] .

Substituting in the equations [4]:

$$P_{inv} = \frac{P_i}{V_{sys} \times \eta_{inv}} = \frac{500}{12 \times 0.95} = 43.9 \text{ w} \quad (3.27)$$

$$S_{inv} = \frac{P_{inv}}{P_f} = \frac{43.9}{0.8} = 54.9 \text{ VA} \quad (3.28)$$

$$I_{inv} = \frac{S_{inv}}{V_{sys} \times \eta_{inv}} = \frac{54.9}{12 \times 0.95} = 4.8 \text{ A} \quad (3.29)$$

$$C_{inv} = (0.4 \frac{\$}{\text{w}}) * P_{rat,inv} = 0.4 \times 500 = 200 \$ \quad (3.30)$$

### 3.5.7 Wiring sizing:

According to calculated total DC power, a (Copper )Wire with the following main data :

Table3.8: Datasheet Wiring.

<b>Required Information</b>		
Resistivity of copper wire	0.0183	<b>Ω.mm</b>
length of the wire(array to battery_)	8	<b>m</b>
length of the wire (battery to inverter)	3	<b>m</b>
length of the wire (inverter to loads)	10	<b>m</b>
Cost of wiring (array to battery) \$/m	0.13	<b>\$/m</b>
<b>Cable Sizing Procedure and Cost Estimate</b>		
Parameter Being Determined	Computed Parameter Value	
maximum current produces by the PV panels	7.5	<b>Amp</b>
Dc voltage drop V(d)	0.7	<b>Volt</b>
DC Cable of cross-sectional area	3.1	<b>mm<sup>2</sup></b>
maximum current at the input of the inverter	4.8	<b>Amp</b>
voltage drop V(d)	2.92	<b>mm<sup>2</sup></b>
AC Cable of cross-sectional area	0.292	<b>mm<sup>2</sup></b>
<b>Total cost of wiring</b>	<b>31</b>	<b>\$</b>

\*For more information check the appendix [Z] & [T]

Substituting in the following equations [4]

$$I_{cable} = I_{scM} \times N_{pm} \times F_{safe} = 7.43 \times 1 \times 1.01 = 7.5A \quad (3.31)$$

$$V_{drob-dc} = V'_{pv} \times 0.05 = 13.3 \times 0.05 = 0.7 \text{ Volt} \quad (3.32)$$

$$A_{dc,cable} = \frac{2 \times L_{dc-cable} \times I_{dc-cable} \times \rho}{V_{drob-dc}} = \frac{2 \times 8 \times 7.5 \times 0.0183}{0.7} = 3.1 \text{ mm}^2 \quad (3.33)$$

$$I_{inv} = \frac{S_{inv}}{V_{dc} \times \eta_{inv}} = \frac{54.9}{12 \times 0.95} = 4.8 \text{ A} \quad (3.34)$$

$$V_D = V_{DC} \times 5\% = 12 \times 0.05 = 2.92 \text{ V} \quad (3.35)$$

$$A_{inv,cable} = \frac{2 \times L_{inv,cable} \times I_{inv} \times \rho}{V_D} = \frac{2 \times 10 \times 4.8 \times 0.0183}{0.6} = 2.92 \text{ mm}^2 \quad (3.36)$$

$$L_{total} = L_{(Array \text{ to battery})} + L_{(battery \text{ to inverter})} = 8 + 3 = 11 \text{ m}$$

$$C_{wire} = \left( \frac{\$}{m} \right) \times (L_{total}) = 2.89 \times 11 = 31\$ \quad (3.37)$$

### 3.6 Protection Design:

Substituting in the following equations [4]

1. Fuse current ( ):
 

$$I_f \geq K_T K_S I_{s.c} \quad (3.38)$$

$$I_f \geq K_T K_S I_{s.c}$$

$K_T$  : safety factor to reflect temp & irradiation.

$K_S$  = short circuit safety coefficient to avoid immediately interruption.

$$I_f = 1.25 \times 1.25 \times 7.43 = 11.6A$$

2. Array Disconnecter:

$$\text{Total Current} = \# \text{ of strings} \times \text{fuse current} = 1 \times 11.6 = 11.6A \quad (3.39)$$

3. Utility Breaker:

$$I_{inv} \geq \frac{P_{ac}}{V_{rated(ac)}} \times 1.25 = \frac{500}{230} \times 1.25 = 2.7A \quad (3.40)$$



Depending on the current values the off grid PV protection design was made as shown on figure(3.16).

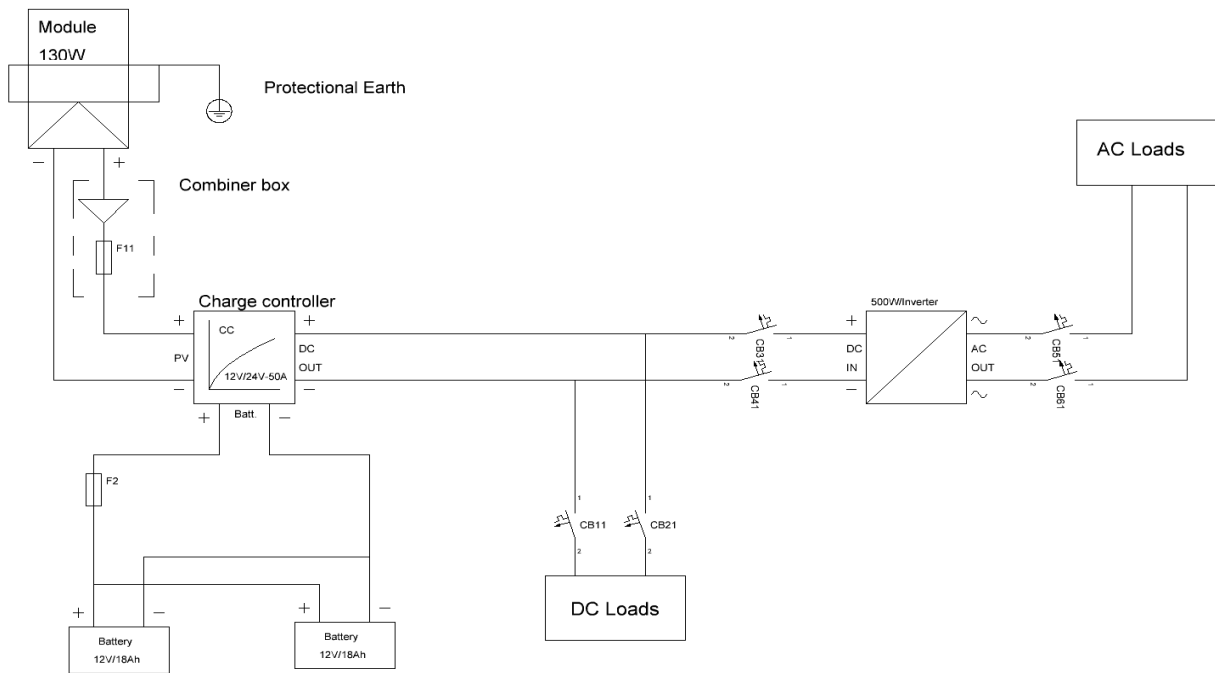


Figure3.16: Protection In Off Grid PV System

### 3.7PV System Cost:

Table3.9: PV System Cost

Num	component	Cost\$	Cost₪
1	Battery	110	412.5
2	Panel	67	251
3	Charge controller	22.5	84.5
4	Inverter	200	750
5	Wiring	31	116.5
<b>Total</b>		<b>430.5\$</b>	<b>1614.5₪</b>

### 3.8 Time Needed To Empty The First Tank Into The Second Tank:

Looking at fig(3.17) and substituting in the following equations:

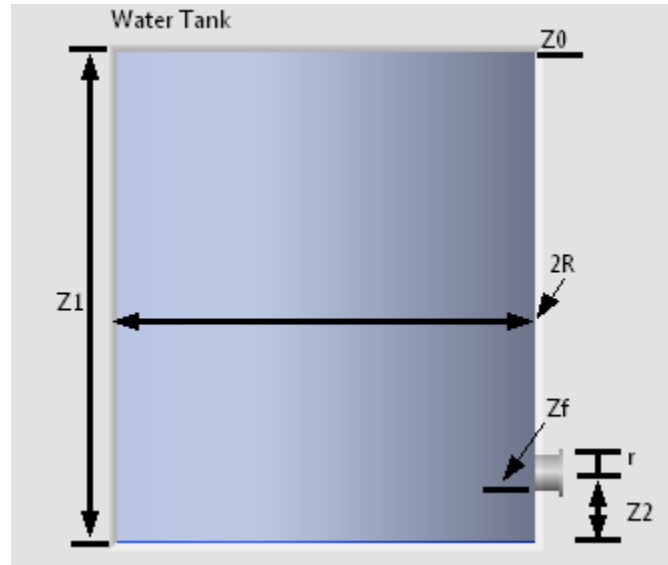


Figure3.17 Water Tank Dimensions

By Bernoulli's equation[1]:

Considering the following conditions:

1. Inviscous .
2. Incompressible.

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 \quad (3.41)$$

$P_1 = P_2 = \text{Atmospheric Pressure .}$

$Z_2 = 0$  , Considered the reference point

$$V_1 \gg V_2 , V_2 = - \frac{dz}{dt}$$

$$V_1 = \sqrt{2gZ_1}$$

$$V_1 A_1 = V_2 A_2$$

$$\sqrt{2gZ_1} * \pi r^2 = - \frac{dz}{dt} * \pi R^2$$

By solving the equation :

$$t = \frac{2R^2 [\sqrt{Z_0} - \sqrt{Z_f}]}{\sqrt{2g} * r^2} = \frac{2 * (0.2)^2 [\sqrt{1.1} - \sqrt{0.1}]}{\sqrt{2 * 9.81} * (14 * 10^{-3})^2} = 338.13 \text{ Second} = 5.635 \text{ Minute}$$

Where :

$P_1$  : Pressure at the surface of the tank.

$P_2$  : Pressure at the outlet of the tank.

$V_1$  : Water Velocity at the surface of the tank.

$V_2$  : Water Velocity at the outlet of the tank.

R: The radius of the tank.

r: The radius of the outlet.

$Z_f$  = The final water level height.

$Z_0$  = The initial water level height.

$Z_1$  = The height from the radius of the outlet to the surface of the tank.

$Z_2$  = The height from the radius of the outlet to end of the tank.

- 4.1 Advantage For Picking LabVIEW**
- 4.2 LabVIEW Interface**
- 4.3 Process Flowchart**
  - 4.3.1 First Tank Process Flowchart**
  - 4.3.2 Second Tank Process Flowchart**
- 4.4 LabVIEW Program Simulation Code**
  - 4.4.1 Pump Code**
    - 4.4.1.1 Pump Working Status Code**
    - 4.4.1.2 Pump Automatic Filling And Emptying Code**
- 4.5 Chlorine Disinfection Code**
  - 4.5.1 PH Adjustment Code**
  - 4.5.2 Chlorine Addition Code**
- 4.6 First Solenoid And Ultraviolet Code**
- 4.7 Ozone Disinfection Code**
- 4.8 Second Solenoid Valve Code**
  - 4.8.1 Second Solenoid Valve (Open/Close) Status Code.**
  - 4.8.2 Second Tank Automatic Water Level Increase And Manual Decrease Code**
- 4.9 Backup Tank**
  - 4.9.1 Backup Tank Interface**
  - 4.9.2 Third Solenoid Valve Work Status Code**
  - 4.9.3 Backup Tank Automatic Filling And Manual Emptying Code**
- 4.10 LabVIEW Simulation**
- 4.11 Future Work**

# Chapter Four: LabVIEW Design And Simulation:

## 4.1 LabVIEW Definition:

LabVIEW is systems engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights.[24]

### 4.1.1 Advantages for picking LabVIEW:

1. Great Interface: where LabVIEW has a wide interfacing system that could be used to show data from electrical devices on and stay connected with the machines even when you are far away.
2. Parellel Process : LabVIEW can perform several tasks at the same time that gives flexibility to the user during programming.
3. Flexibility with saving data: LabVIEW has the ability to save data in files in devices in different forms that makes the process able to study and improve after being analyzed.

## 4.2 LabVIEW Interface:

The process is watched through the interface shown in figure(4.1):

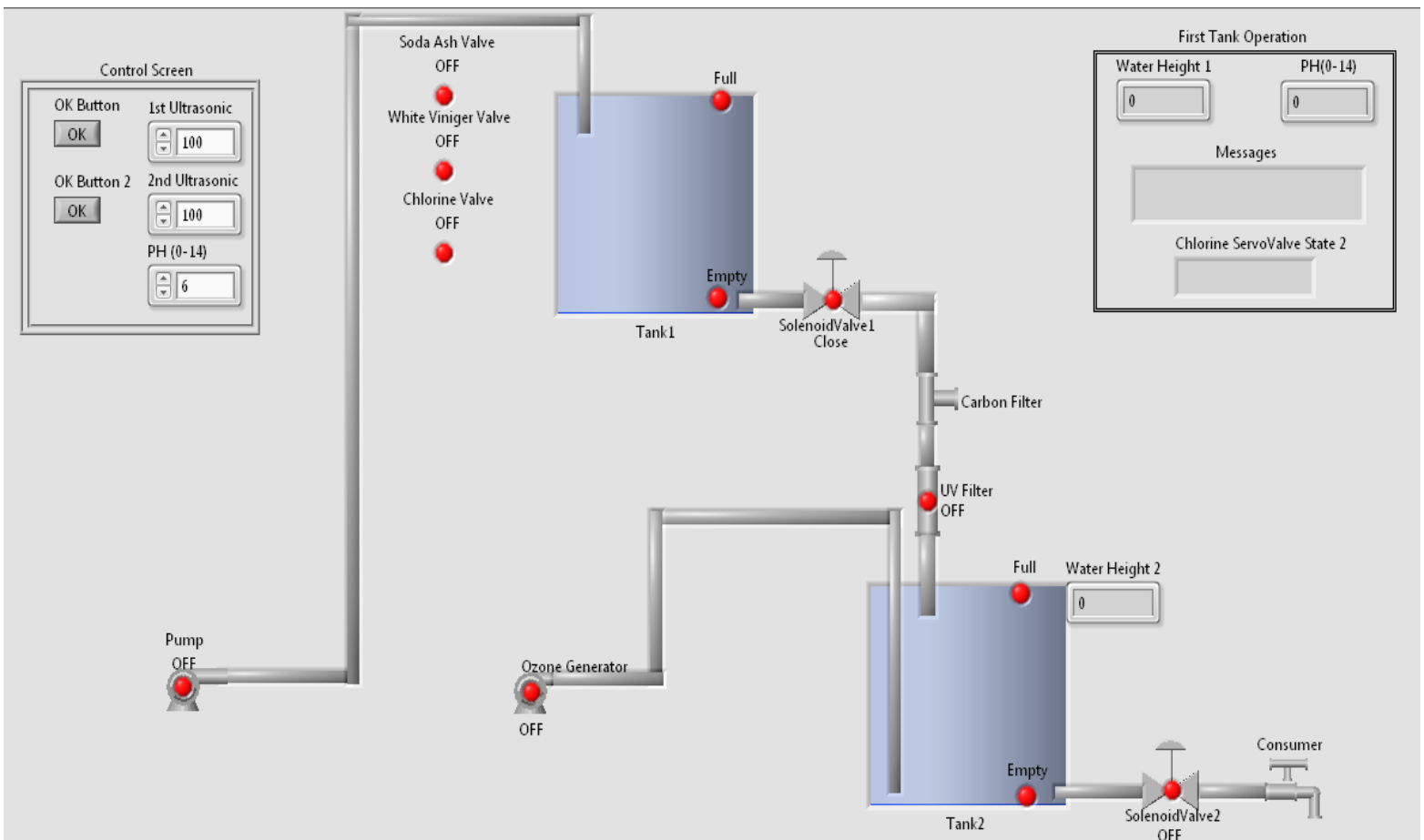


Figure4.1 System LabVIEW Interface

### 4.3 Process Flowcharts:

The Process is divided into two parts as shown.

#### 4.3.1 First Tank Process Flowcharts:

The first tank has independent process to second tank as shown on figure(4.2):

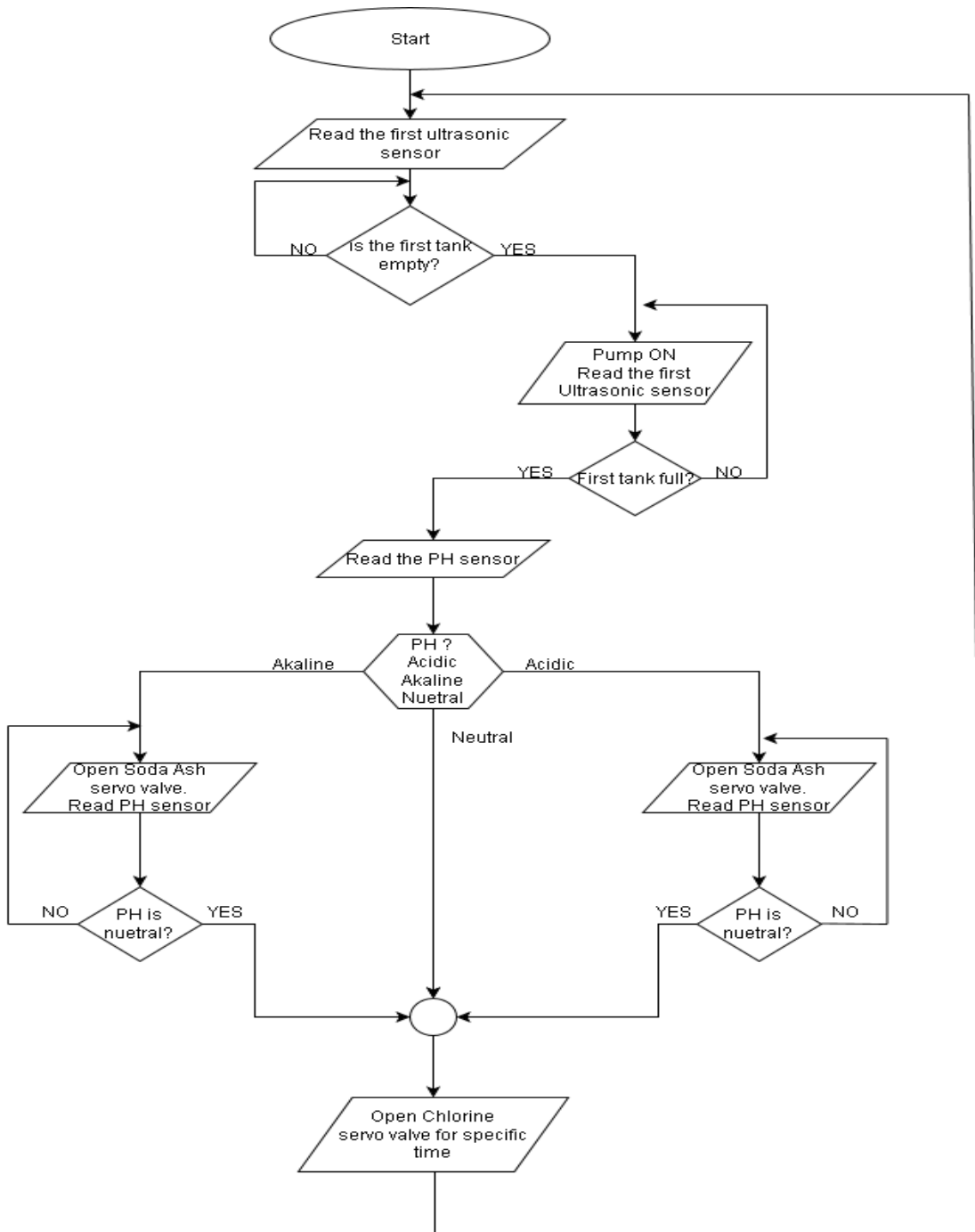


Figure4.2 First Tank Process Flowchart

### 4.3.2 Second Tank Process Flowchart:

The second tank depends on the end of the process of the first tank and the consumption of water as show on figure(4.3):

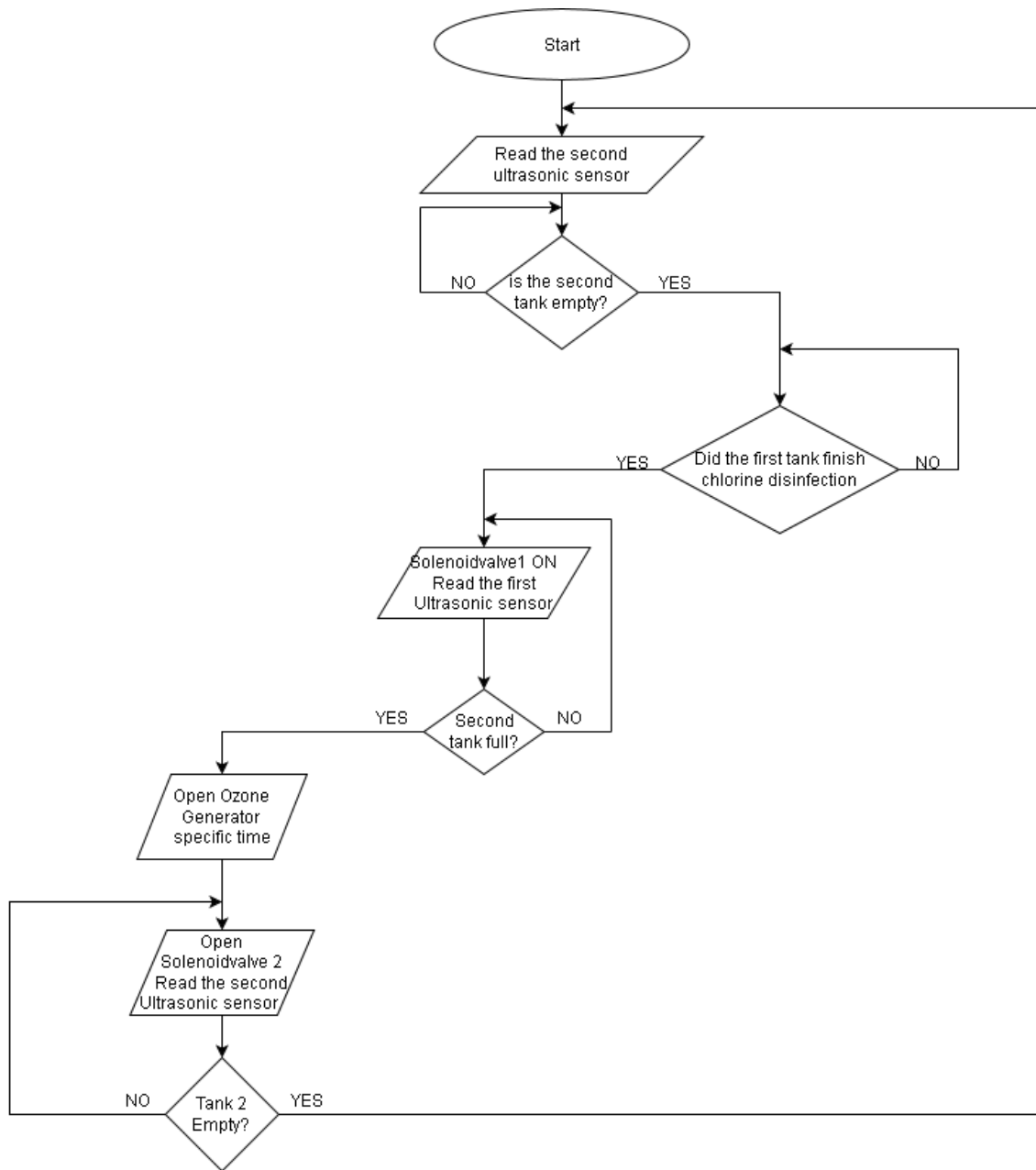


Figure 4.3 Second Tank Process Flowchart

## 4.4 LabVIEW Program Simulation Code:

LabVIEW can be programmed as parallel operation as shown in the following codes were every code controls a part of the process that may be independent to the other depending on the requirements.

### 4.4.1 Pump Code:

The Pumps code is divided to two codes as show below.

#### 4.4.1.1 Pump Working Status CODE:

The pump works when the first tank is empty and stops working when the first tank is closed as shown on figure(4.4):

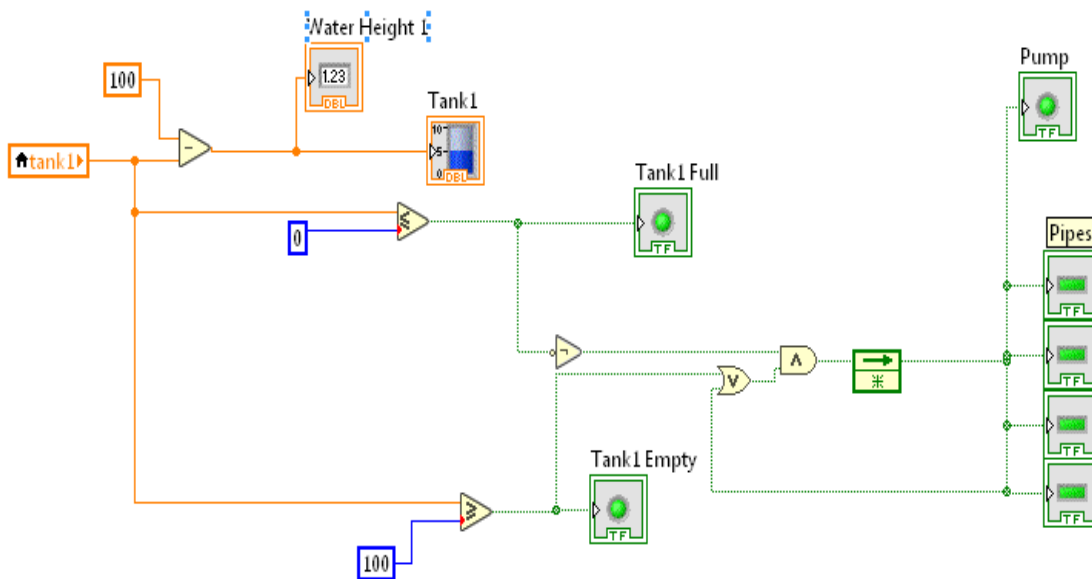


Figure4.4 Pump Working Status Control Code



#### 4.4.1.2 Pump Automatic Filling And Emptying Code:

The water level in the tank increases when the pump is on and decreases when the pump is off with time as shown on figure(4.5):

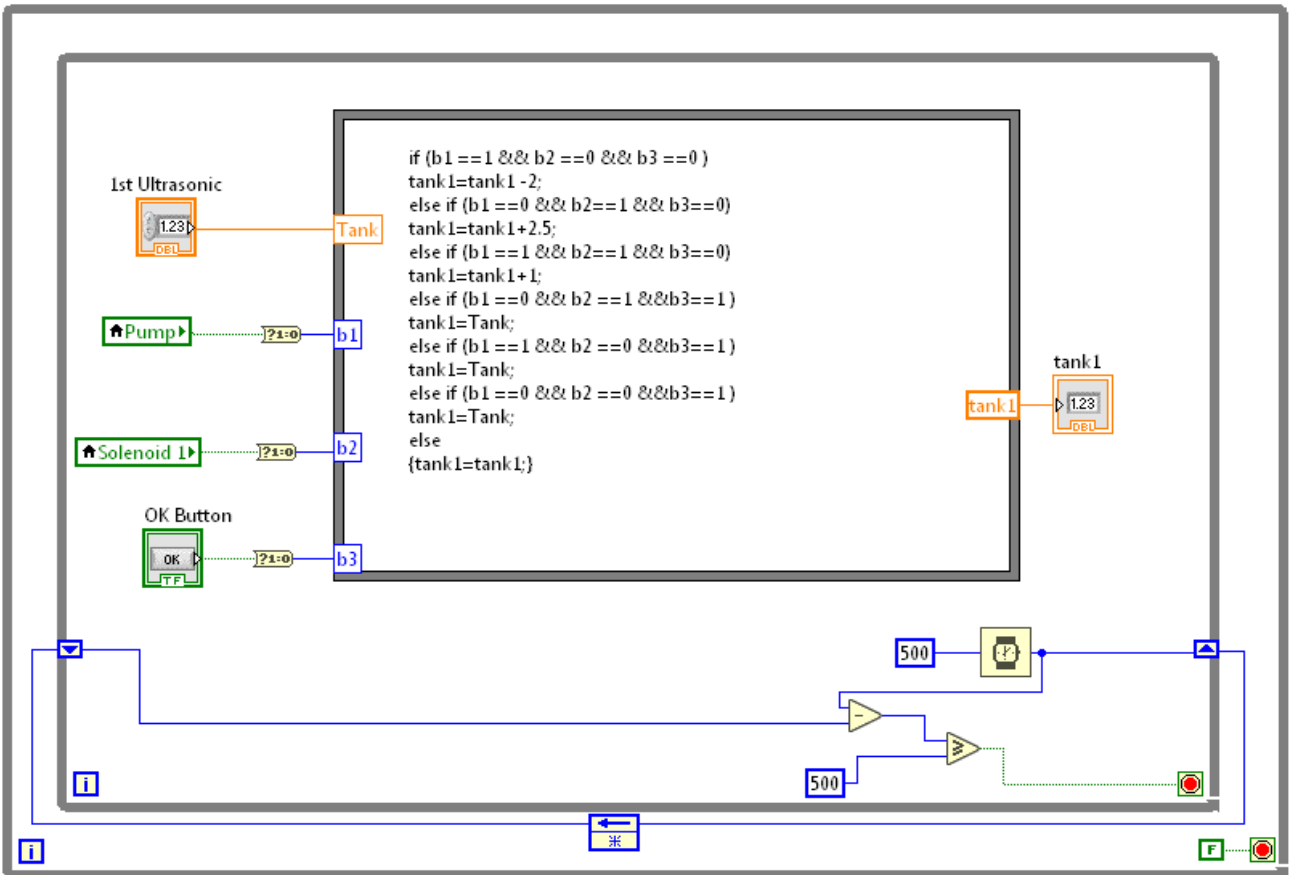


Figure4.5 First Tank Automatic Filling And Emptying Code

## 4.5 Chlorine Disinfection Code:

Chlorine disinfection is dependent to the previous state which is PH adjustment as shown below:

### 4.5.1 PH Adjustment Code:

If the first tank is not full then the PH Adjustment process won't start in the case shown on figure(4.6).

After the first tank is full of water the PH is measured by the PH sensor four cases ,the first case if it is full and the PH is neutral as shown on fig(4.6.a) then it is read for the next step which is chlorine disinfection but if it is not neutral it is either acidic as shown on fig(4.6.b) and the soda ash servo valve opens to pour drops of the solution in the tank until its neutralized or it is alkaline as show on fig(4.6.d) so the white vinegar servo valve opens to pour drops in the tank until the PH becomes neutralized ,or the PH sensor reads a number out of the range (0-14) so the process stops until the sensor gives a right value giving an error as shown on figure(4.6.e) :

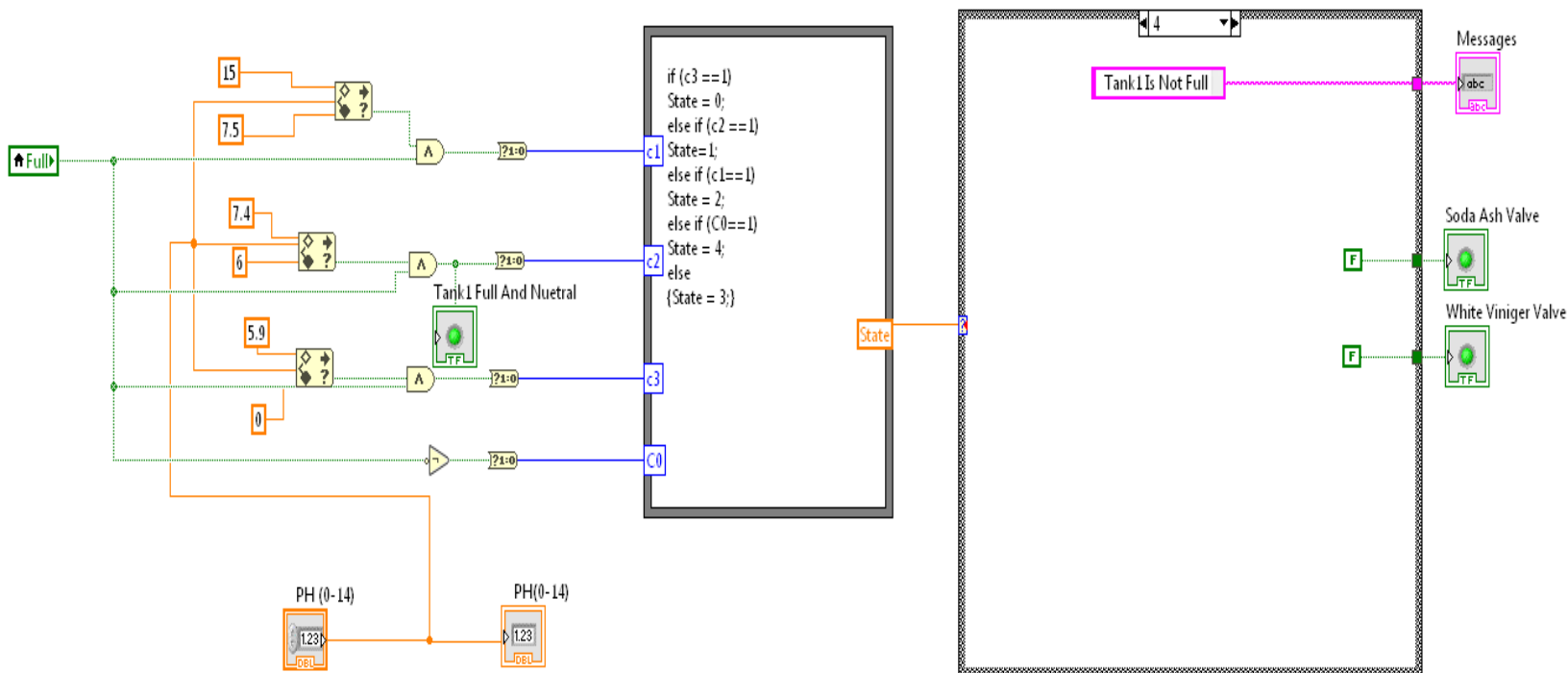


Figure4.6 PH Adjustment And Water Level Detection Code

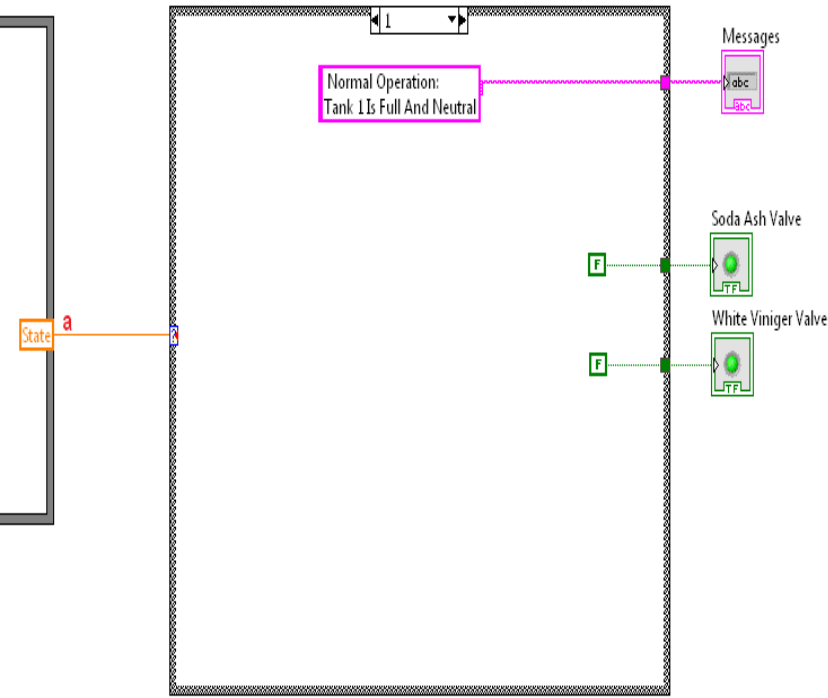


Figure4.6.a First Tank Is Full And Neutralized Case

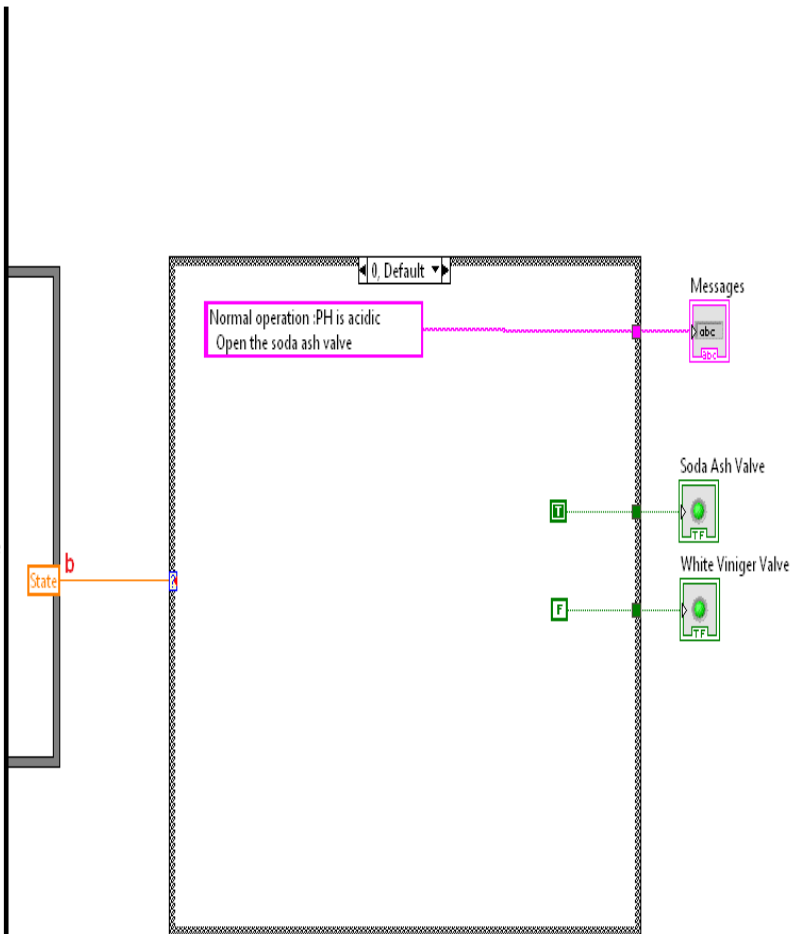


Figure4.6.b First Tank Is Full And Acidic Case

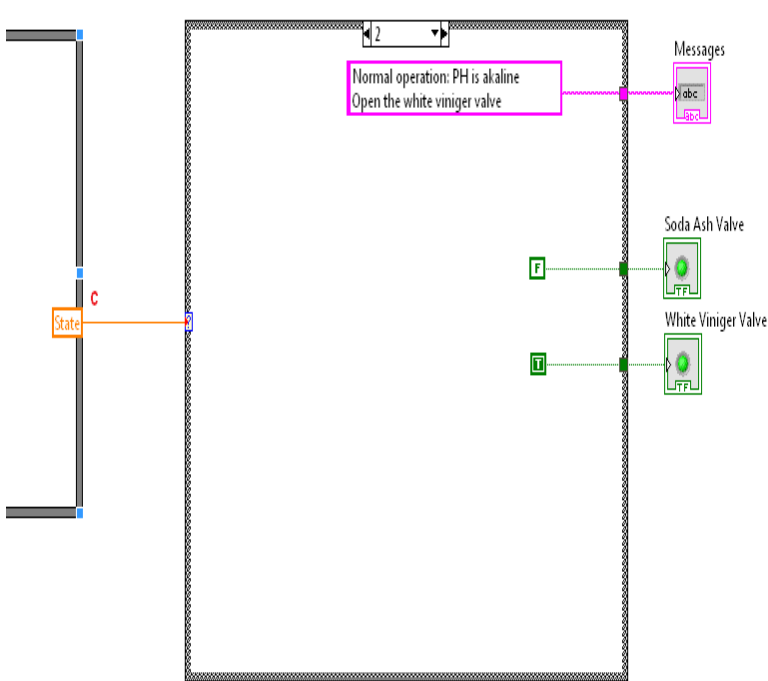


Figure4.6.c First Tank Is Full And Alkaline Case

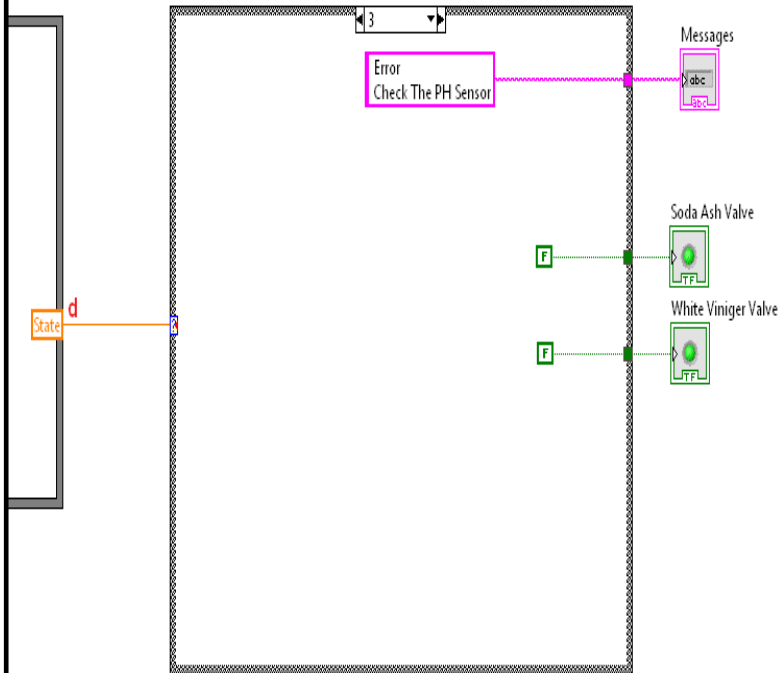


Figure4.6.d Error PH Is Out Of The Acceptable Range

#### 4.5.2 Chlorine Addition Code:

After the PH is adjusted to neutral in the range (6-7.5) , the chlorine servo valve opens to pour drops of chlorine solution in the first tank for disinfection as shown on figure(4.7)

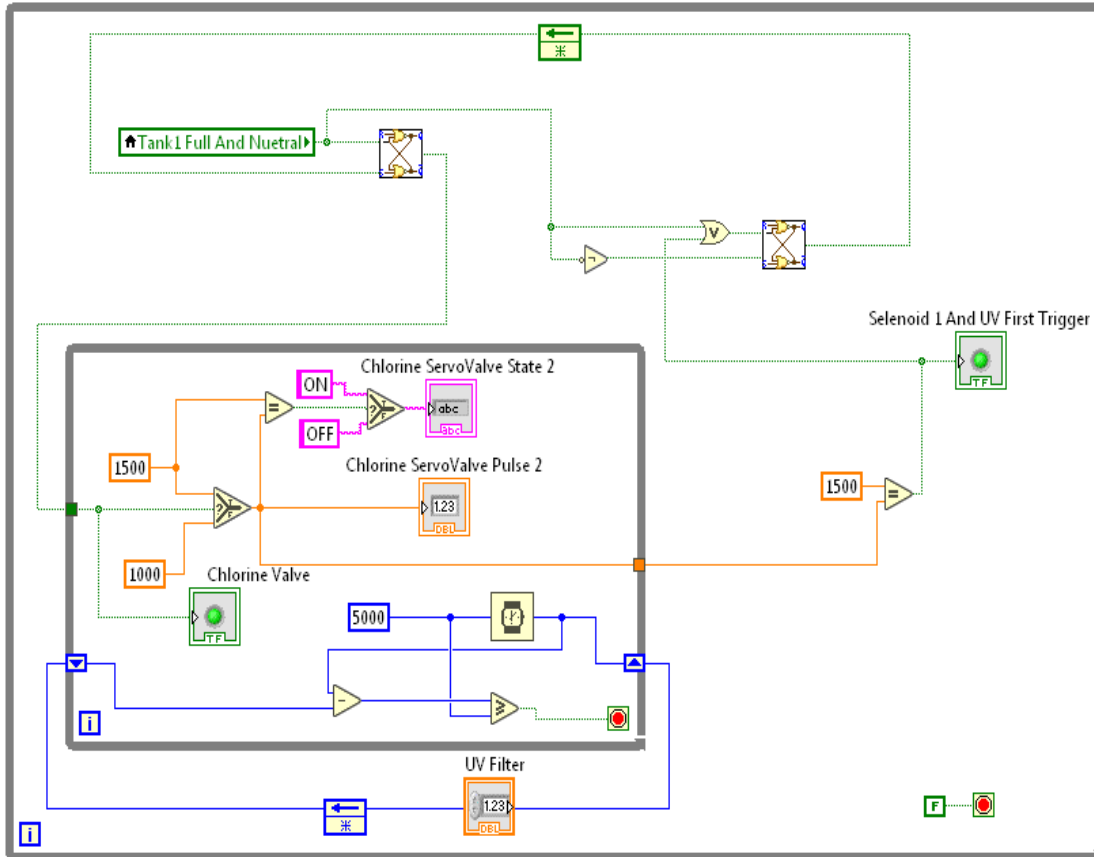


Figure4.7 Chlorine Addition Code

## 4.6 First Solenoid Valve And Ultraviolet Code:

After the first tank finishes its filtering process and the second tank becomes empty the first solenoid valve and the ultraviolet lamp turn on until the second tank is full as show on figure(4.8):

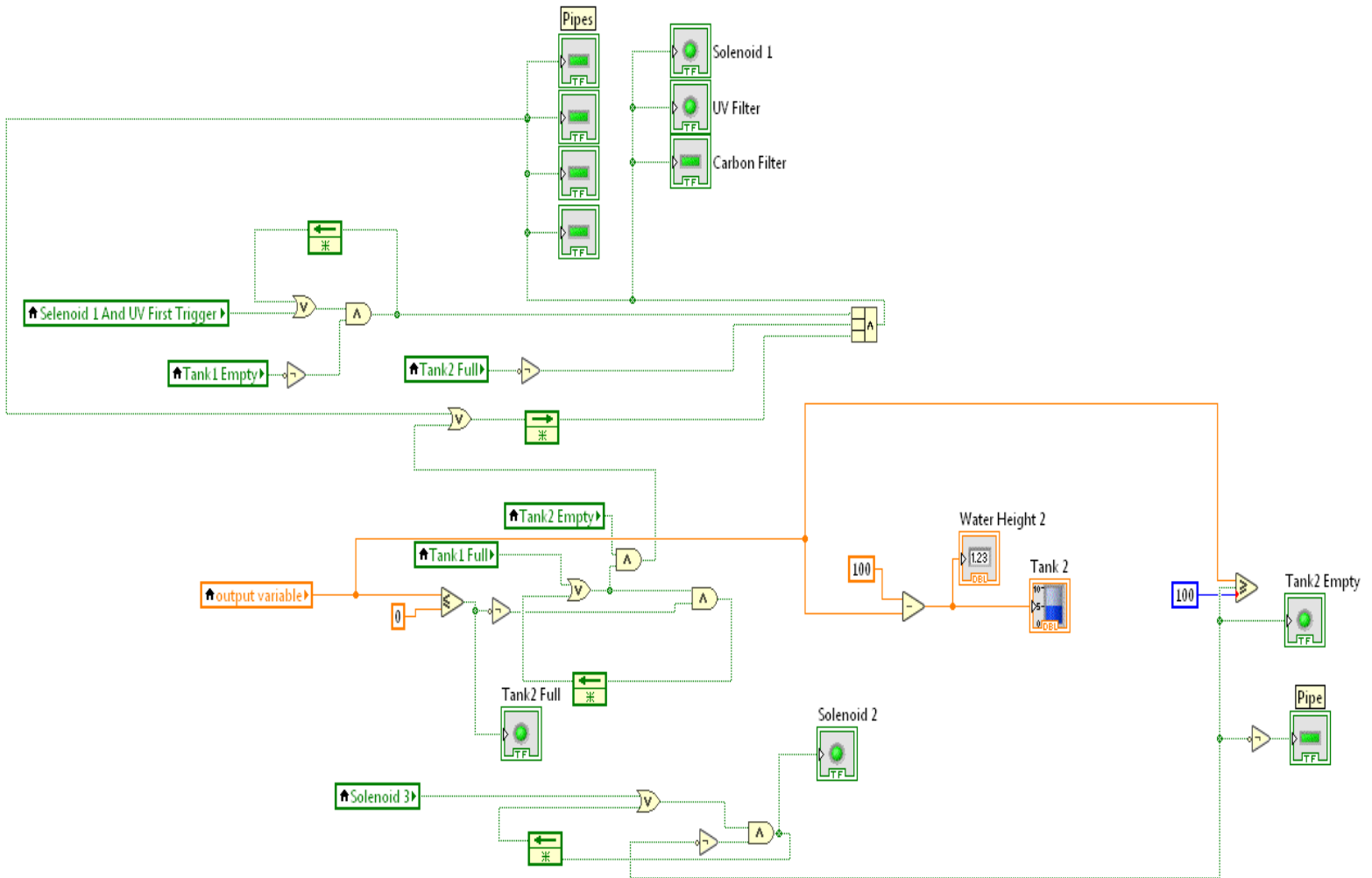


Figure4.8 First Solenoid Valve And Ultraviolet Working Status Control

## 4.7 Ozone Disinfection Code:

After the second tank is full the ozone generator turns on 10 minutes compressing air inside the second tank's water to disinfect it then turns off as shown on the figure(4.9):

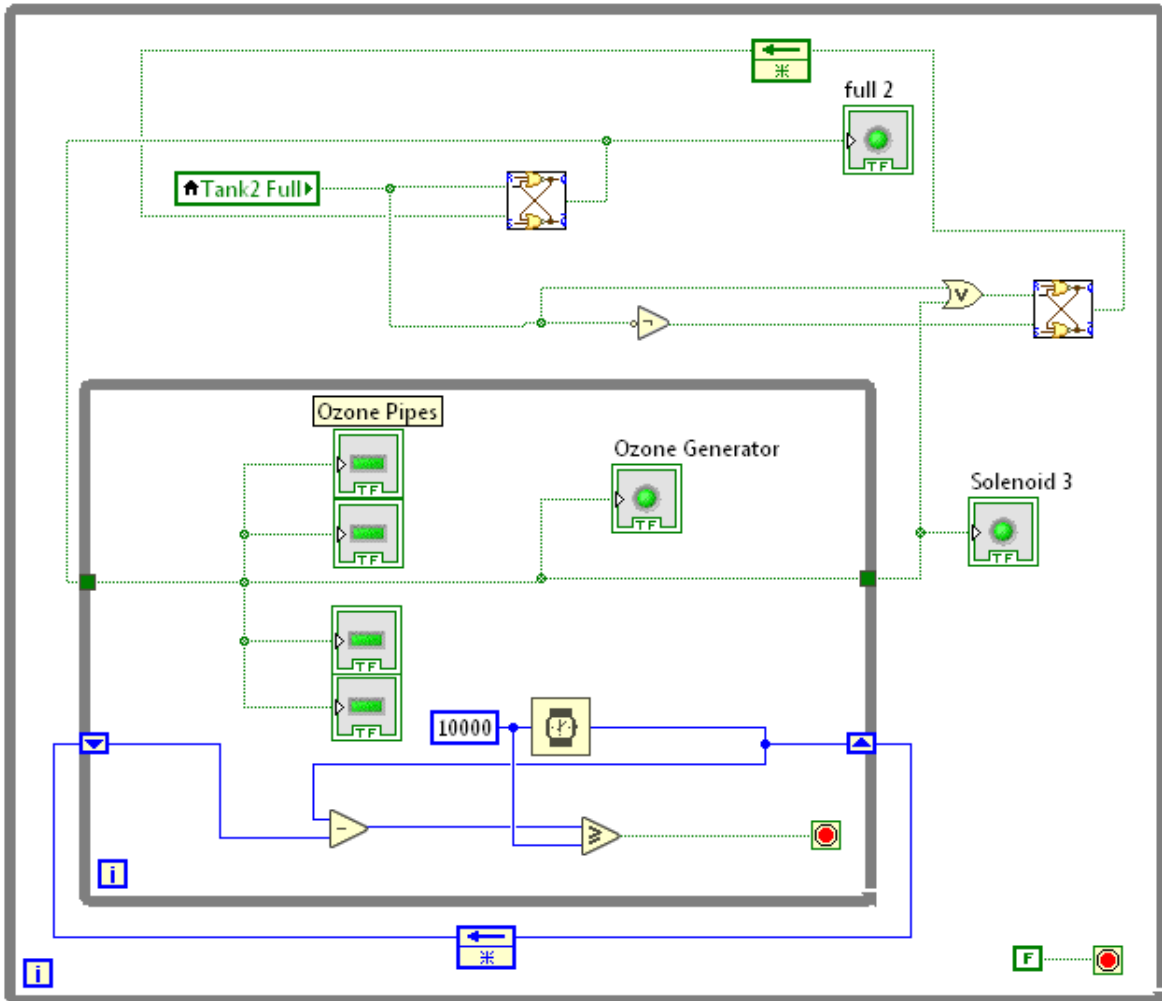


Figure4.9 Ozone Disinfection Process Code

## 4.8 Second Solenoid Valve Code:

### 4.8.1 Second Solenoid Valve (Open , Close) Status:

After the water is disinfected by ozone the second solenoid valve opens to provide the consumer water and closes when the second tank is empty to restart the filtering process as shown on figure(4.10):

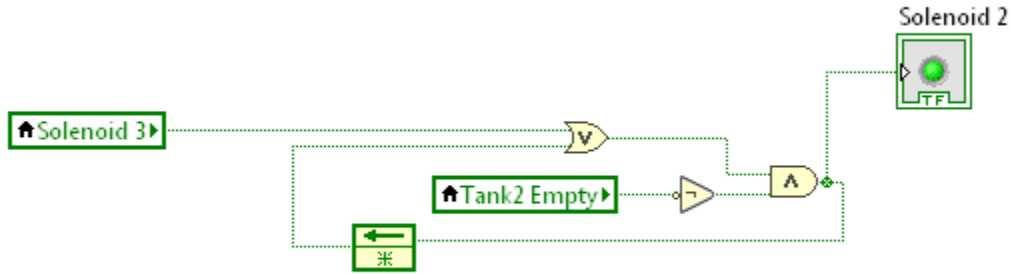


Figure4.10 Second Solenoid Valve Working Status

### 4.8.2 Second Tank Automatic Water Level Increase And Manual Decrease Code:

When the first solenoid valve is open the second tank's water level increases with time until it is full and it decreases by writing a number as an input in the numerical control 2nd ultrasonic in the simulation manually as show on figure(4.11)

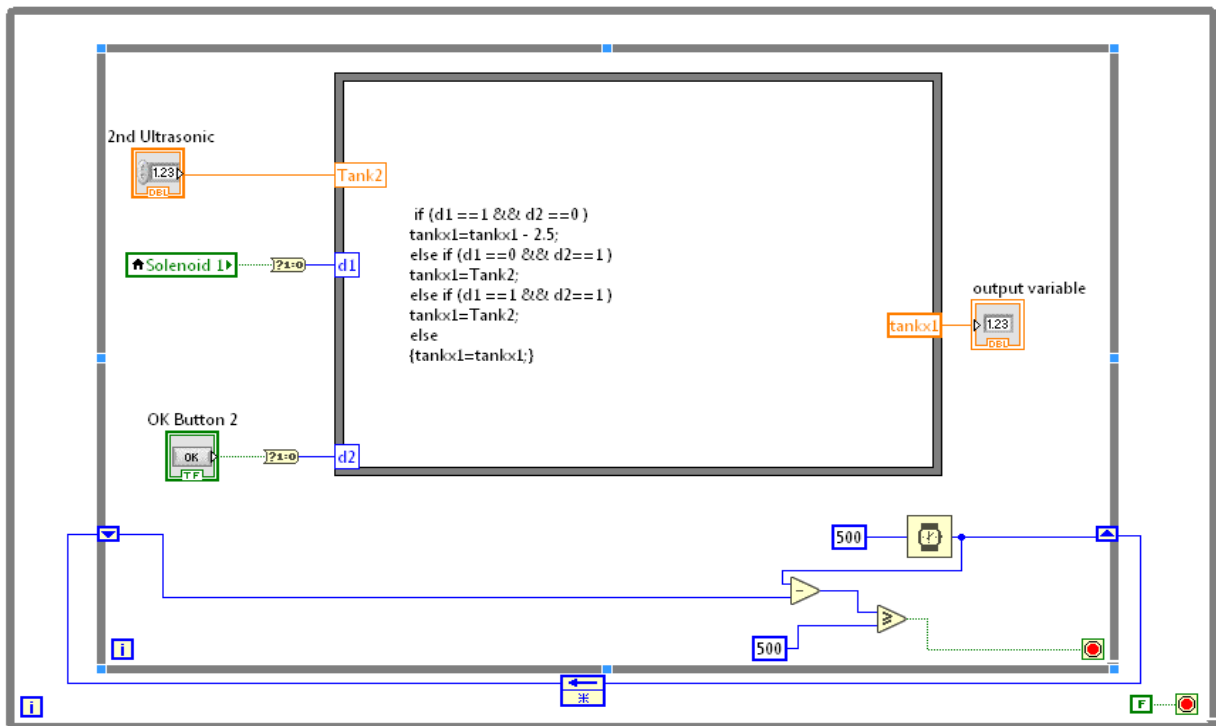


Figure4.11 Second Tank Automatic Water Level Increase And Manual Decrease Code

## 4.9 Backup Tank :

A backup tank could be added to the system to provide the consumer with water in cases of emergency that stops the system or to avoid waiting for the second tank to finish its filtering process by adding the following codes and adjusting the second tank automatic filling and emptying code as shown .

### 4.9.1 Backup Tank Interface:

The backup tank is added to the system as shown on figure(4.12):

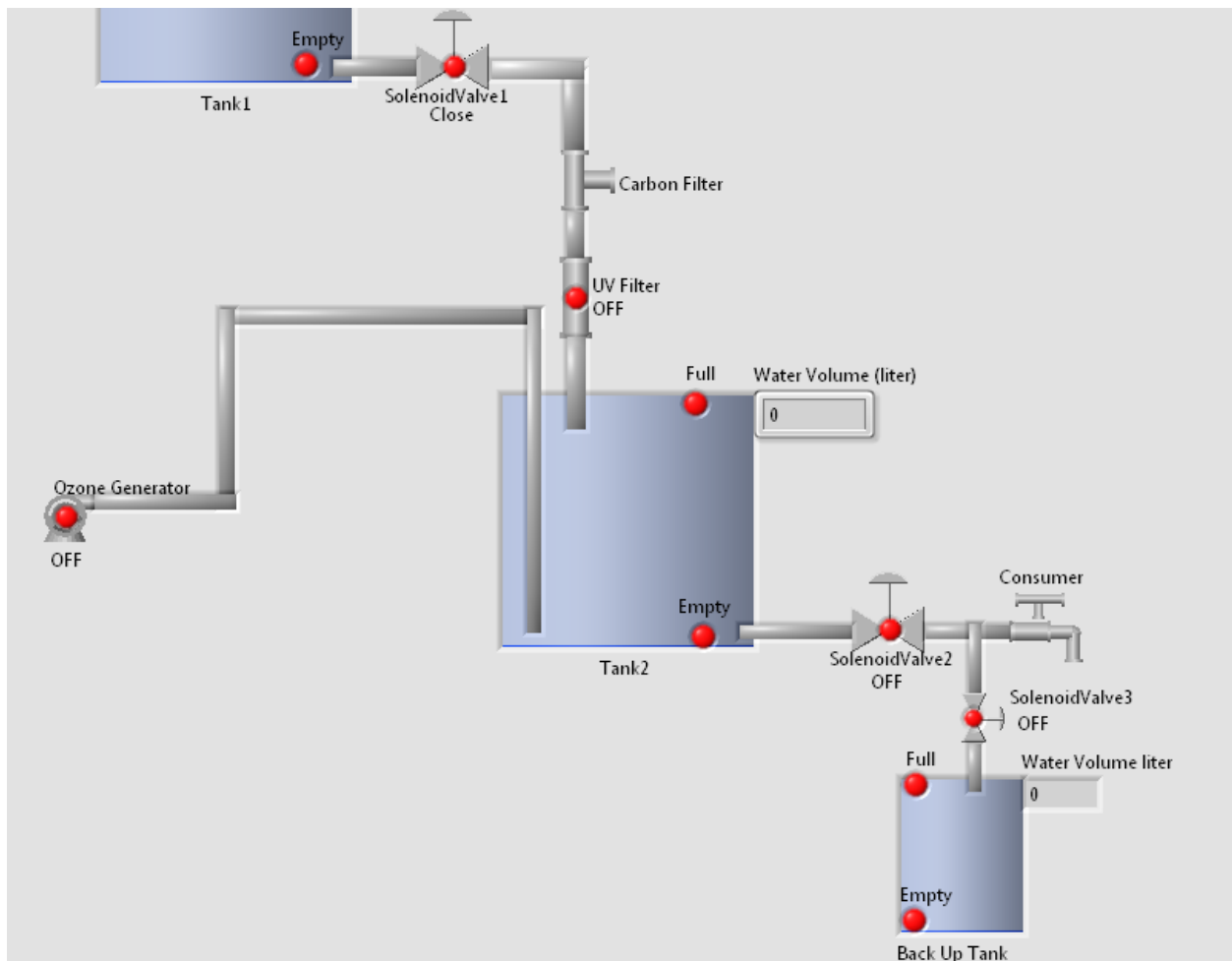


Figure4.12 Backup Tank Interface



### 4.9.2 Third Solenoid Valve Work Status Code :

The third solenoid valve opens when the backup tank and the second solenoid valve is open and provide the backup tank with disinfected water is empty and closes when the backup tank is full as show on figure(4.13):

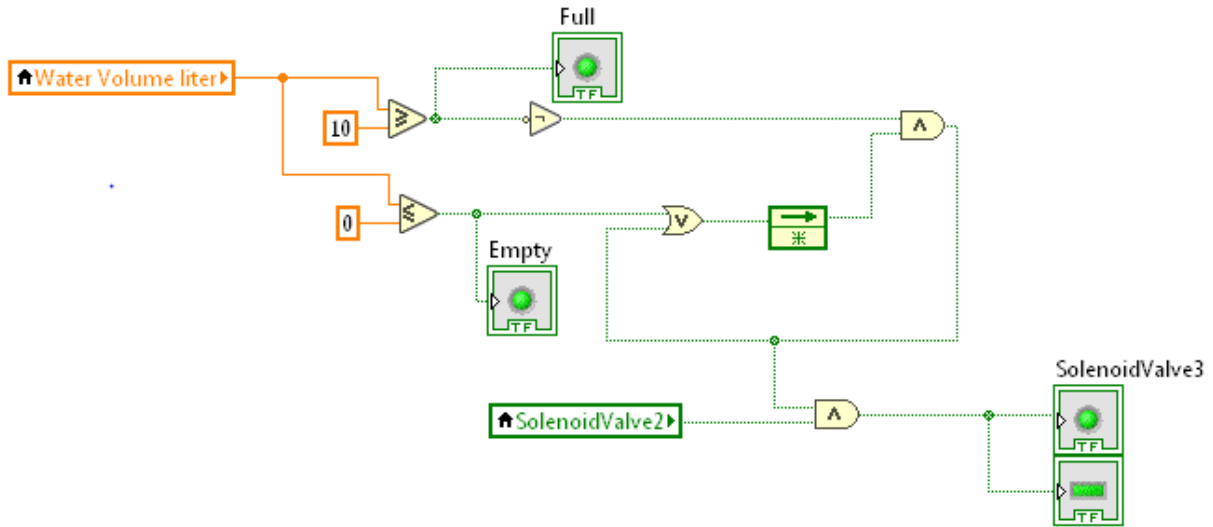


Figure4.13 Third Solenoid Valve Work Status Code

### 4.9.3 Backup Tank Automatic Filling And Manual Emptying Code :

The backup tank's water level increases when the third solenoid valve opens and decreases when the manual boolean switch (B.U Tank) is switched on until the tank becomes full or empty as shown on figure(4.14).

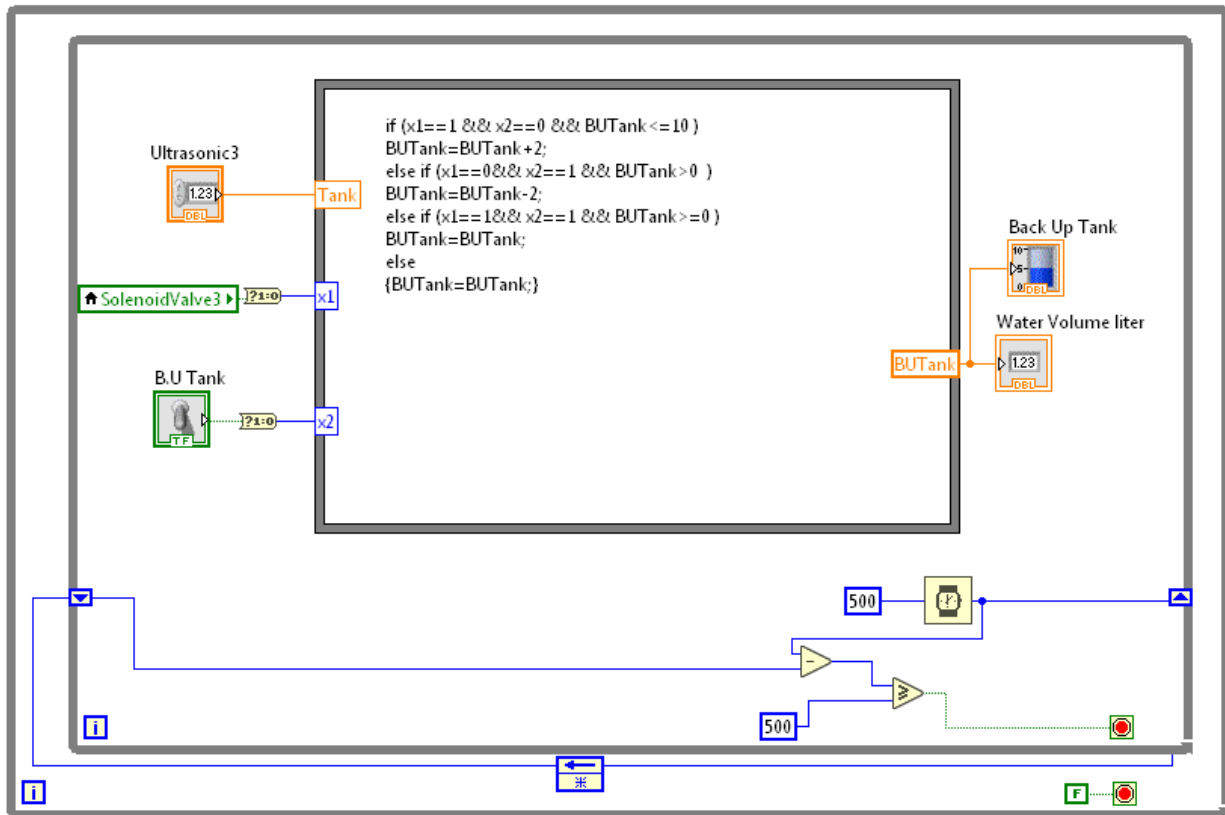


Figure 4.14 Backup Tank Automatic Filling And Manual Emptying Code

## 4.10 LABVIEW Simulation:

After testing the code in the simulation the code worked in the following steps:

1. The pump turned on whenever the first tank was empty and turned off whenever it gets full as shown on figure(4.15):

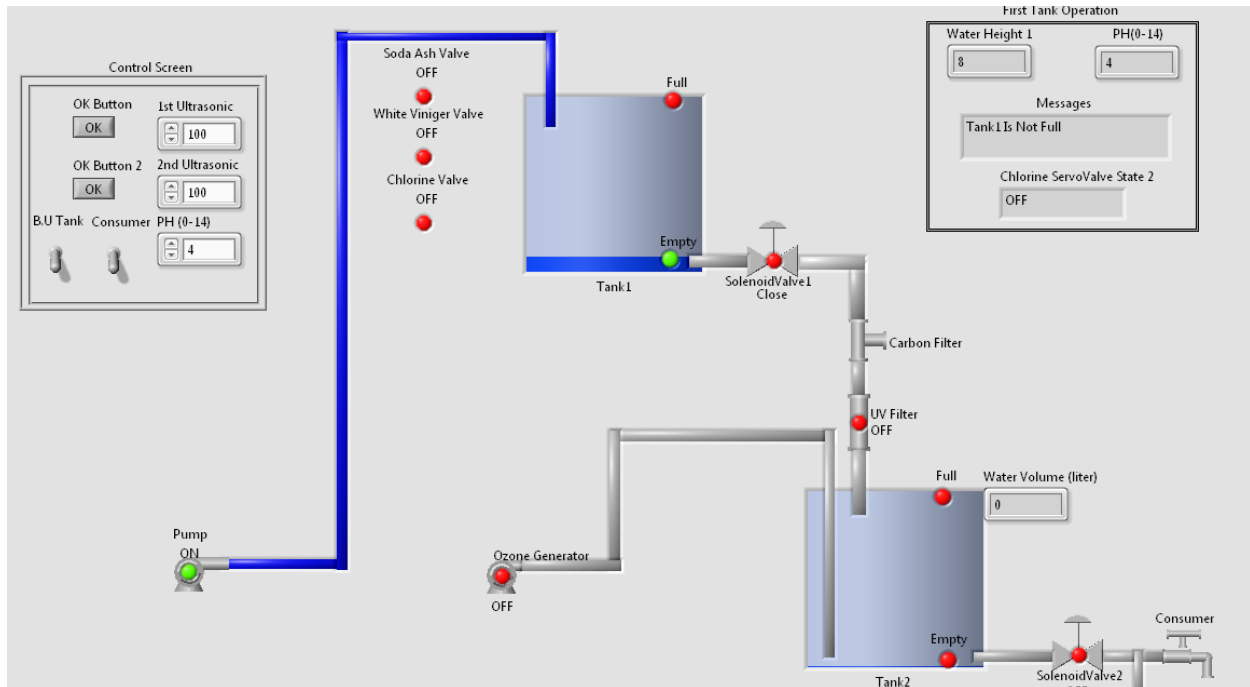


Figure 4.15 Pump Working Due to Tank Becoming Empty

2.The PH was adjusted when it was acidic and alkaline until it became neutral after turning on the white vinegar or the soda ash valves as shown on figures(4.16),(4.17):

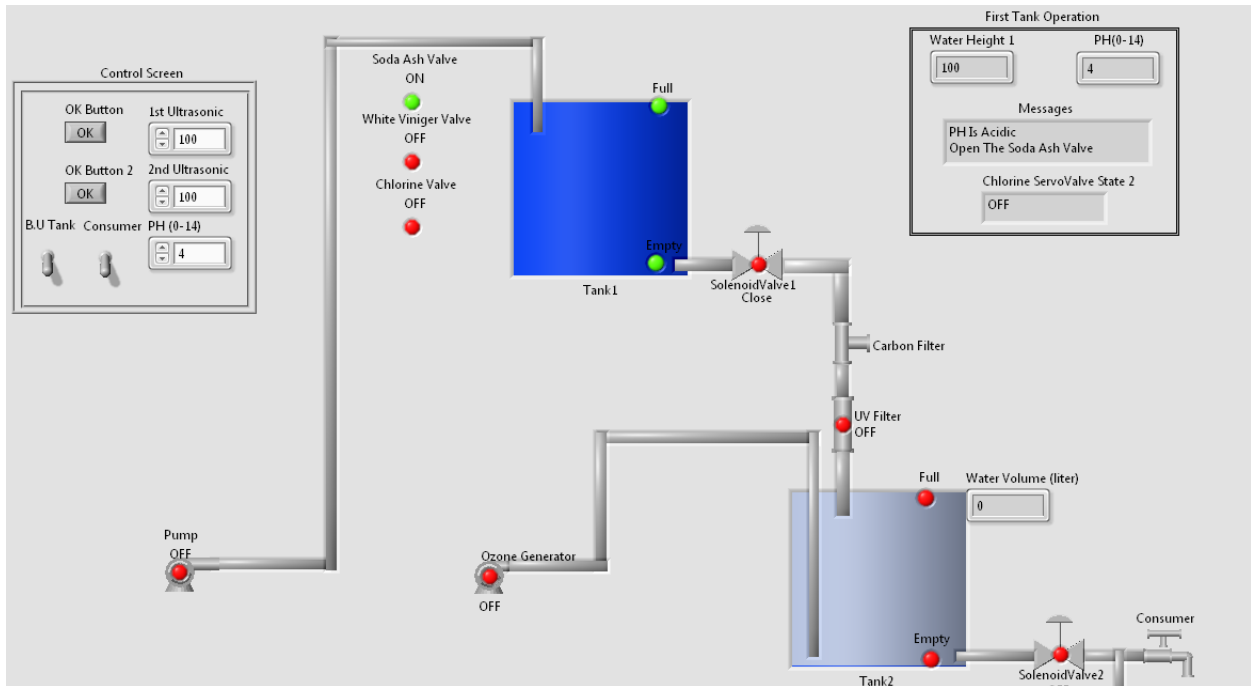


Figure 4.16 Adjusting Acidic PH By Soda Ash

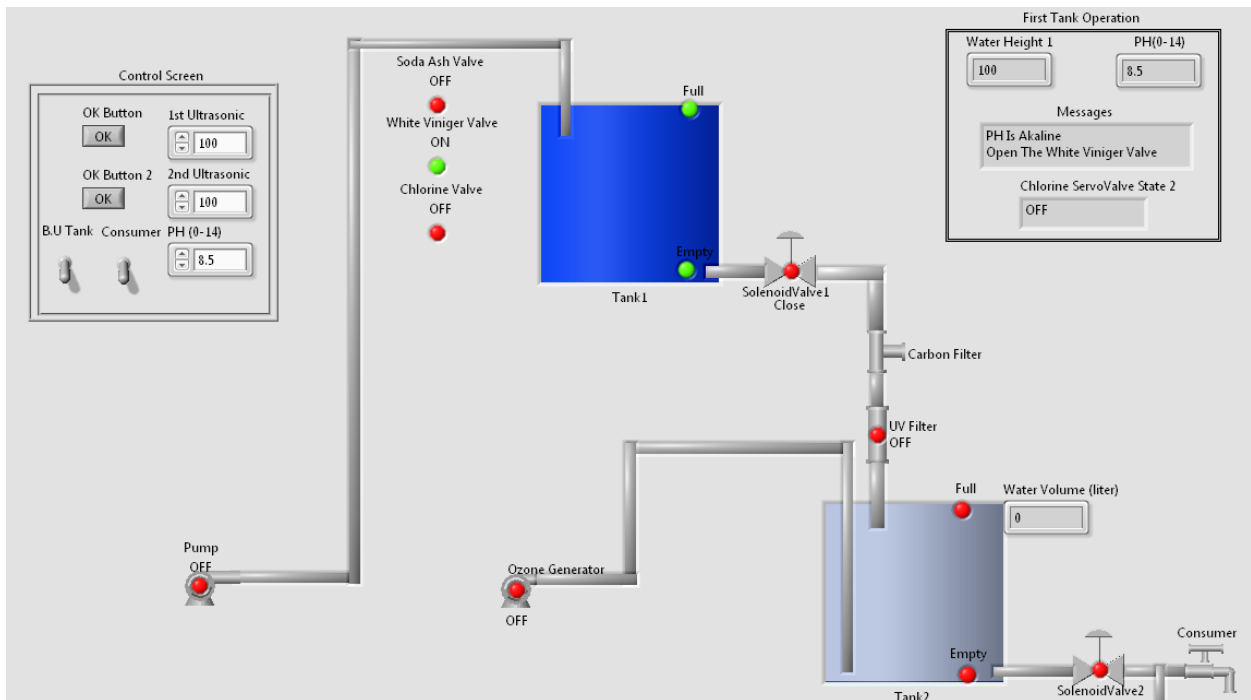


Figure 4.17 Adjusting Alkaline PH By White Vinegar

3. Opening the chlorine valve for specific time after the PH became neutral for disinfection as show on figure (4.18):

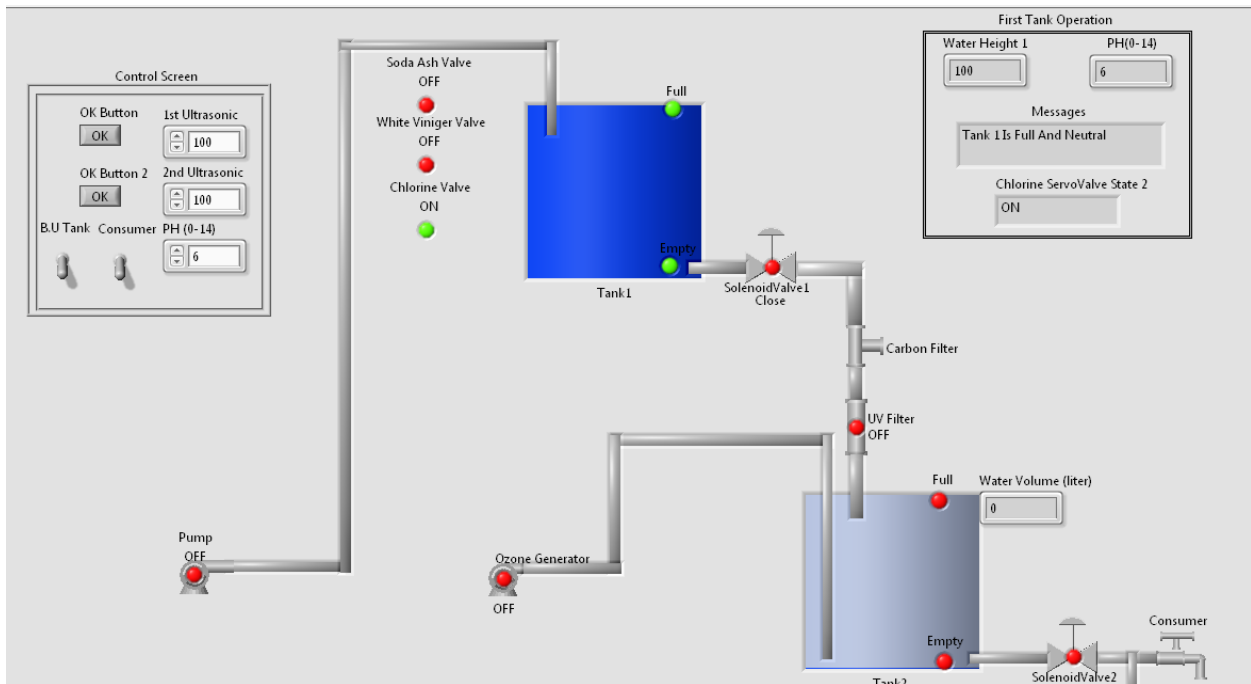


Figure4.18 Chlorine Valve On For Disinfection

4. Opening the solenoid valve and ultraviolet filter to disinfect and move the water from the first tank to the second tank as shown on figure(4.19):

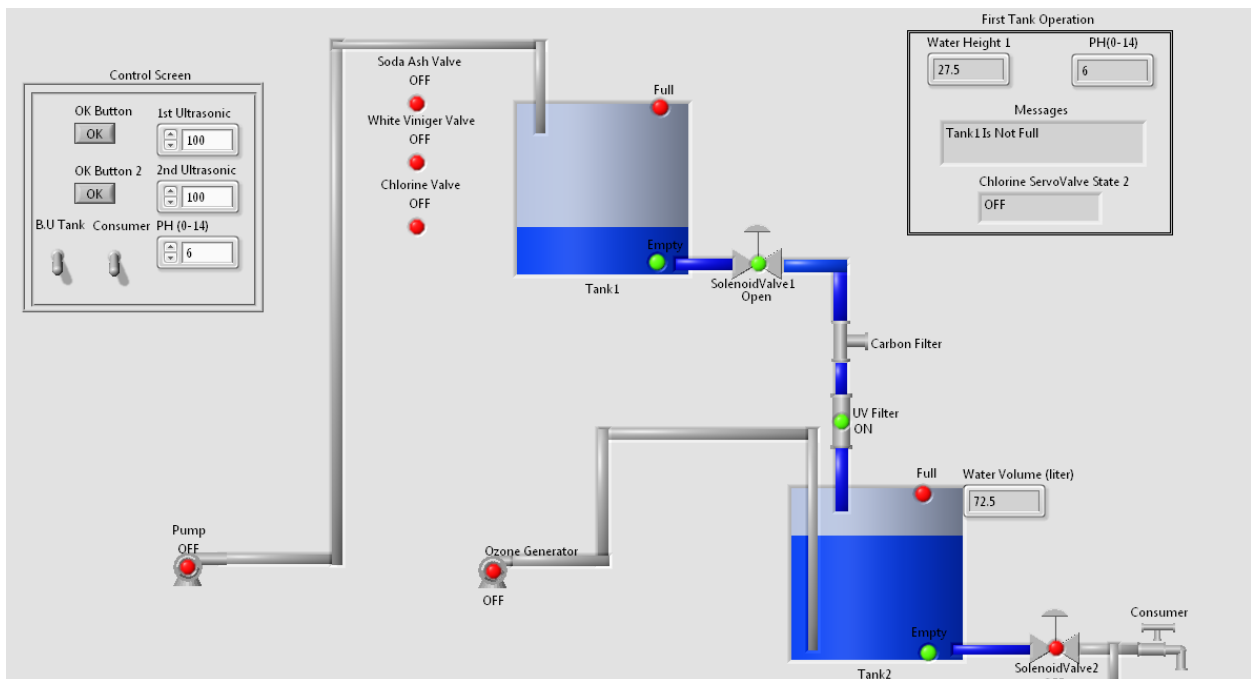


Figure4.19 Water Disinfected And Emptying From The First Tank To The Second Tank

4. Water Disinfected by compressing ozone air in the water tank after the second tank is full then turning off after 10 minutes as shown on figure(4.20):

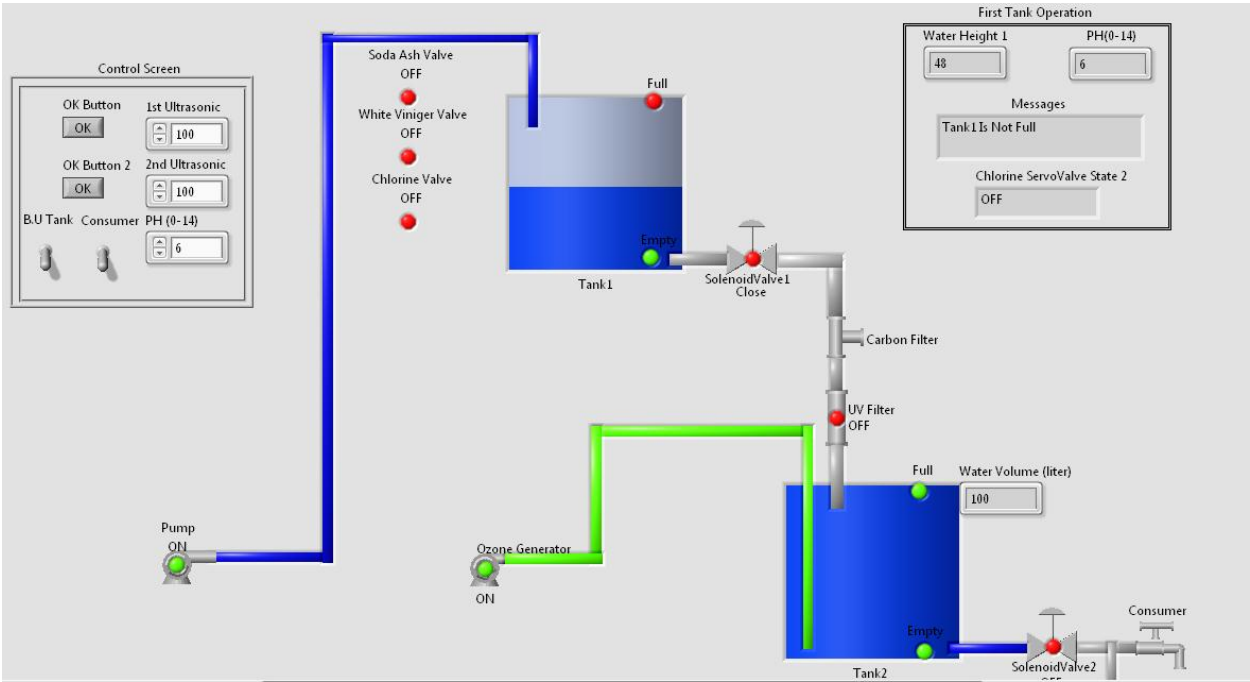


Figure4.20 Ozone Disinfecting Water

4. The second and third solenoid valves open immediately the third solenoid valve until the back up tank is full and the second tank is empty as shown on figures (4.21) , (4.22) and (4.23) :

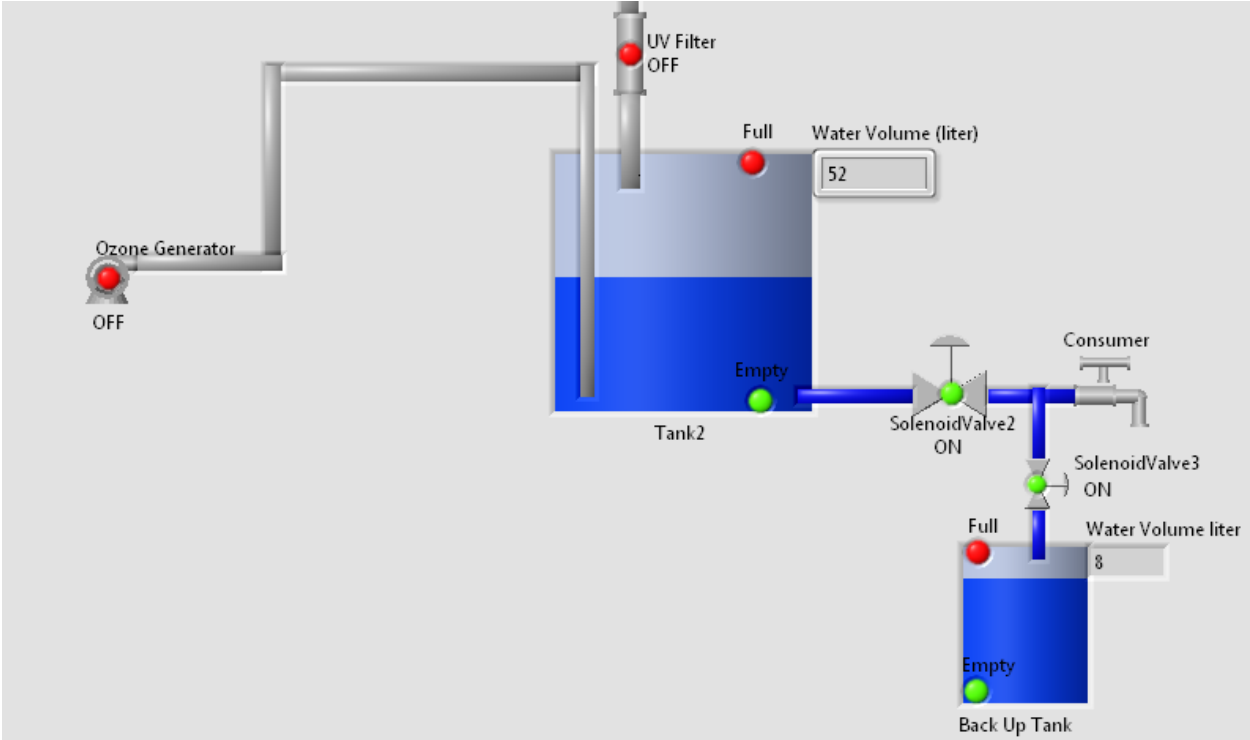


Figure4.21 Second And Third Solenoid Valves Working Status

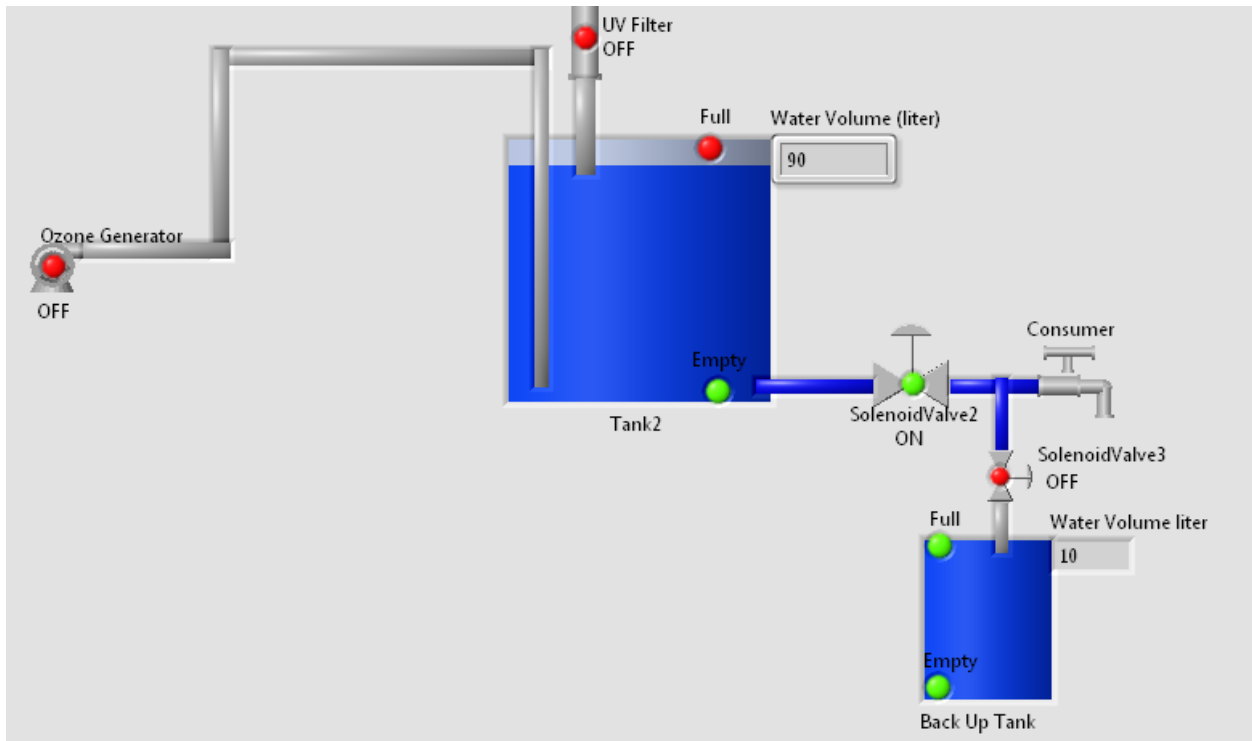


Figure4.22 Third Solenoid Valve Closing After Filling The Backup Tank

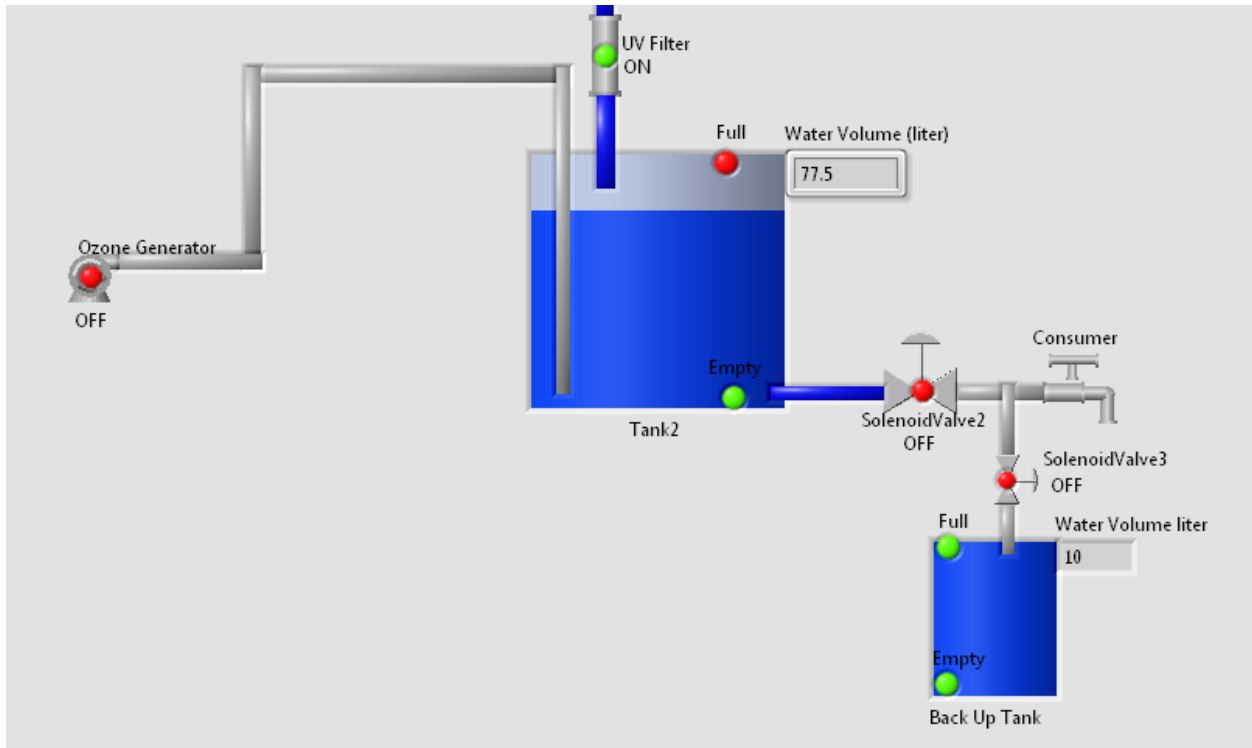


Figure4.23 Second Solenoid Valve Closing After The Emptying the Second Tank And Refilling It

## **4.12 Conclusion:**

This project presented a filtering system that was provided by a photovoltaic energy source that were designed to filter the water through four stages and simulated on the program LabVIEW, and was to be constructed but stopped due to quarantine after the disease COVID-19 spread through the world.

## **4.12 Future Work:**

The system can be improved by :

- 1.adding the ability of viewing the process and errors through a far away monitor or phone wireless .
- 2.Increasing the disinfection accuracy by adding new filters and filtering technologies or replacing some of the filters used with more efficient filters in the future.
- 3.Improving error detection by sensors and other ways in the system.
- 4.Decreasing the project cost by replacing devices with cheaper devices with the same efficiency and work.



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